ENGINEERING NEWS

A JOURNAL OF CIVIL, MECHANICAL, MINING AND ELECTRICAL ENGINEERING

Vol. 62. No. 21. 220 Broadway, New York, November 18, 1909.

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The Linda Vista Bridge: A Reinforced-Concrete Trestle, Pasadena, Cal.*

The Arroyo Seco at Pasadena, Cal., is a river bed which is dry for the larger part of the year but through which, during about three months there is a flow sometimes reaching as deep as 6 ft. and with considerable velocity. On the line of Colorado St., where it crosses the gorge, there has been for some time a wooden truss bridge, with two 130-ft. spans and trestle approaches, but during the past year this structure has been superseded by the reinforced-concrete trestle viaduct, described and illustrated in this article.

The viaduct, known locally as the Linda Vista Bridge, is shown in detail in Fig. 2. It consists of six girder spans resting on five tower bents, and abutting on the ends on the high bank of the valley. The whole length is divided into panels of 17 ft. 3 ins., each bent being of that length and each span being divided into three of such spaces by the transverse floor beams, making a span length for each girder of 51 ft. 9 ins.

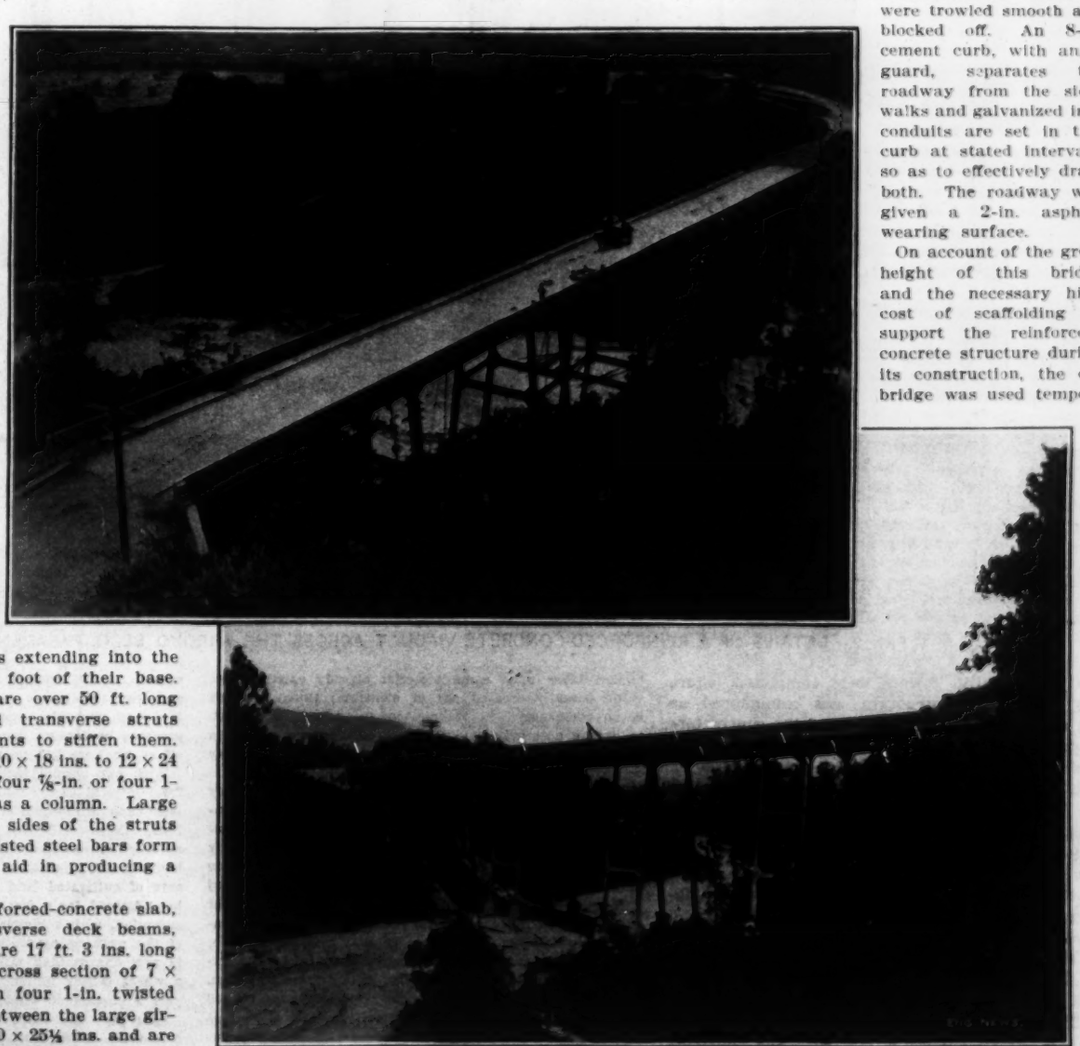
The towers consist of four columns each. These columns are 18 ins. square and reinforced with eight 1¼-in. round steel bars extending into the pier footings to within one foot of their base. Nearly all of the columns are over 50 ft. long and have longitudinal and transverse struts framing into their third points to stiffen them. The struts vary in size from 10 × 18 ins. to 12 × 24 ins. and are reinforced with four ⅞-in. or four 1-in. twisted steel bars laced as a column. Large brackets on top and bottom sides of the struts reinforced with two ¾-in. twisted steel bars form knee braces and materially aid in producing a rigid connection.

The deck consists of a reinforced-concrete slab, longitudinal stringers, transverse deck beams, and girders. The stringers are 17 ft. 3 ins. long and 6 ft. on centers with a cross section of 7 × 19½ ins. and reinforced with four 1-in. twisted steel bars. The deck beams between the large girders have a cross section of 10 × 25½ ins. and are reinforced with six 1⅛-in. twisted steel bars. In the tower spans these transverse beams were increased to 12 × 30 ins. to add lateral stiffness. The large girders, 51 ft. 9 ins. long, extending from tower to tower, have a cross section of 16 × 58½-ins., and are reinforced with nine 1⅜-in. twisted steel bars in tension and three 1⅜-in. round steel bars in compression. In the tower bent the longitudinal girders are the same size as the 50-ft. girders and are reinforced with four 1-in. twisted steel bars. Corbels were used on the longitudinal girders and shear bars and stirrups were provided for all stresses. The sidewalk is carried on small cantilever beams or brackets at every panel point, on the outside of the large girders.

Two expansion joints were provided on the outer ends of the portion consisting of the three central towers with their two connecting girder spans. These are shown in detail in Fig. 3. This facilitated construction, also, as it enabled the contractor to erect and complete this central portion of the bridge, remove a portion of the forms from the same and use them in turn on the west and east sections, which consist of a single tower and two girder spans.

The whole structure was given a pebble dash finish of cement on the outside and the sidewalks were trowled smooth and blocked off. An 8-in. cement curb, with angle guard, separates the roadway from the sidewalks and galvanized iron conduits are set in this curb at stated intervals, so as to effectively drain both. The roadway was given a 2-in. asphalt wearing surface.

On account of the great height of this bridge and the necessary high cost of scaffolding to support the reinforced-concrete structure during its construction, the old bridge was used temporarily for a working platform and staging to erect and help carry the new structure. In order to utilize the old bridge, the design of the new structure was such that it could straddle the old trusses and the final plans gave a 20 ft. clear



TWO VIEWS OF THE LINDA VISTA BRIDGE.

*Prepared from information furnished us by Messrs. Mayberry & Parker, Los Angeles, Cal., who were the engineers on the viaduct.

roadway between curbs, with 4-ft. sidewalks on each side.

It was necessary to carry the foundations of this bridge deep enough to preclude the possibility of a remote chance of their being undermined by the occasional floods. In view of the fact that this stream carries but little drift, it was feasible to use isolated piers under the columns. These piers extended from a level of some 8 ft. above the lowest point in the river bed to from 10 to 16 ft. below this point. They are 6 ft. square at the bottom and 3 ft. square at the top.

On excavating for these footings considerable water was encountered and on two of the central towers the contractors were obliged to pump day and night to keep down the water level. Even then it was not possible to pump the crib dry with the available plant, and it became necessary to deposit concrete under water, with a tremie. The work of putting in these pier footings was pushed rapidly and concrete deposited continuously in order to get above the water level. This was perfectly successful. All of the footings for the three central towers were completed before any of the superstructure was commenced as the rainy season was at hand and the contractors were anxious to get above high water with the work as soon as possible.

Although this bridge was designed for a 20-ton roller, there was none available when it came time to make the required test. The heaviest roller available weighed 14 tons. This roller was run across the bridge several times in order to thoroughly test all parts of the structure. Observations were made as to the amount of deflection on each of the big girders on both sides of the bridge, the roller being brought to a stop at the center of each girder and readings taken. The maximum deflection in any girder was only 1/1200 of the span, which was perfectly satisfactory to all parties interested. The construction was carried out under the direction of Mr. Ivory C. Noble, County Surveyor of Los Angeles County; the designing and supervising engineers, were Messrs. Mayberry & Parker, of Los Angeles, and the contractor, the J. F. Hall-Martin Construction Co., of Los Angeles.

A competing design for this bridge was submitted, consisting of a steel viaduct some 20 ft. shorter, with wooden floor joist, deck and rail. Bids were called for on both plans and the lowest bid for the reinforced-concrete structure was only $3,700 more than the lowest bid for the wood and steel bridge. The reinforced-concrete bridge is a permanent structure with practically no cost of maintenance and was designed to carry a load 50% greater than the wood and steel bridge. The total cost of this bridge, including engineering and inspection fees, was $22,054.67, only $1.95 per surface foot of roadway and side-walk.

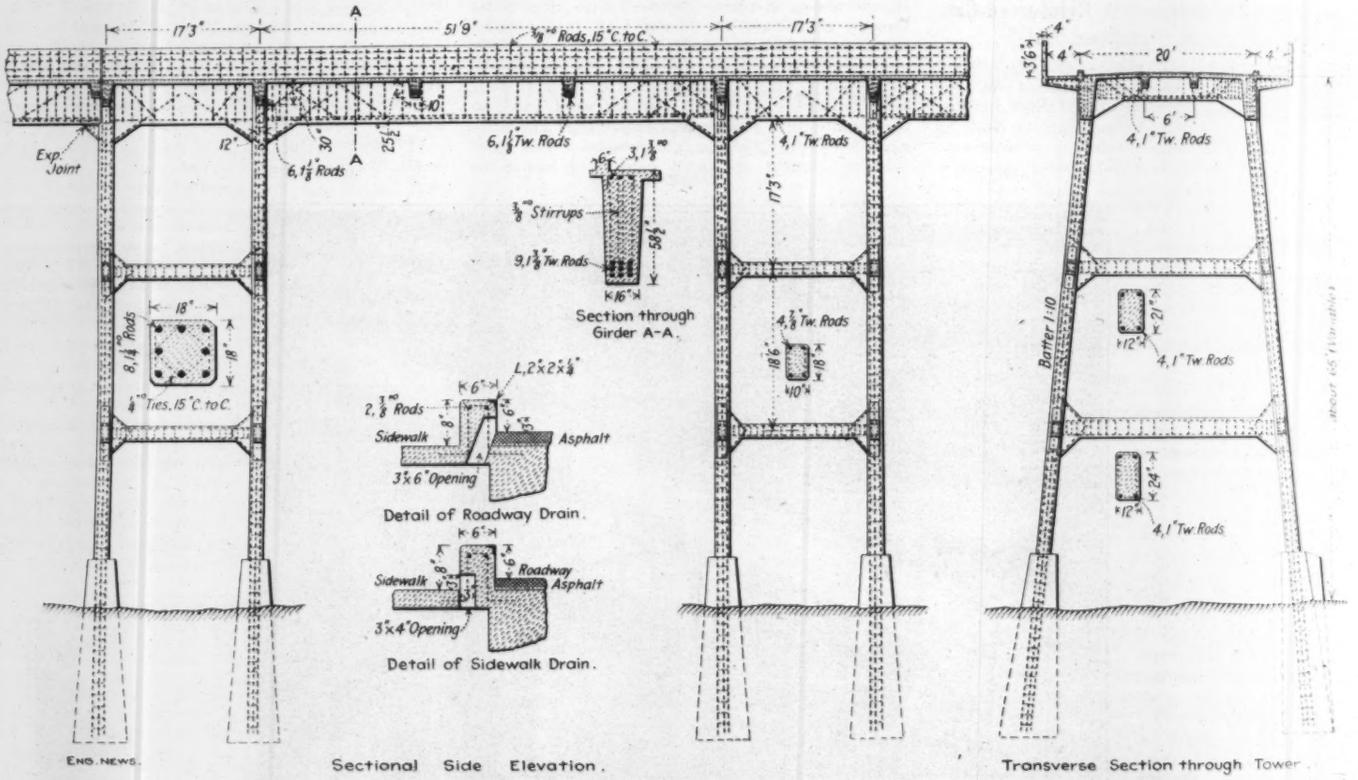


FIG. 2. DETAILS OF A REINFORCED-CONCRETE VIADUCT ACROSS THE ARROYO SECO, PASADENA, CAL.

National Wealth and the Farm.*

By JAMES J. HILL, Chairman of the Board, Great Northern Railroad.

The public is now to some extent awake to the relative value of the different occupations as sources of wealth. The farm is our main reliance. Every other activity depends upon that. The farms of this country are now adding annually over eight billion dollars to the total of our assets; a total which, unlike that of manufacturing and other industries, represents not value conferred by human labor upon some material already existing, but value actually created out of elemental things. There is no comparison, in volume, in value and in relation to human enterprise and the very continuance of human life between the cultivation of the soil and any other occupation.

So far the majority of people will agree. What they fail to realize practically is the declining status of agriculture in this country. They are misled by the statistics of farm values and products, mounting annually by great leaps, into thinking that this absolute increase implies a relative advance of this industry as compared with others. Exactly the opposite is the case. I refer not merely to the quality and results of our tillage, concerning which something may be said a little later on, but to the settling of the human tide away from the cultivated field and toward the factory gate or the city slum.

In 1790 only about 3.4% of the American people lived in towns. At the time of the Civil War the percentage had risen to 16. In 1900 more than 31% of our population was urban. The change is portentous; and there is no doubt that the coming census will show it to have proceeded in the last ten years with accelerated speed. The percentage of our population who work on the farm constantly declines. If that proceeds too far, it is as if dry-rot had eaten through the timbers supporting some great structure.

From all the states, East and West alike comes the complaint that the children will not stay on the farm, and that other labor cannot be enticed there except by high wages for a few weeks in summer. It is quite probable that the new census will show this rural population reduced to 30% of the whole. We have now and have been for more than a generation, in the midst of our boasted progress, in the grip of a revolution that has preceded declining wealth and falling institutions wherever it appeared since history began.

The effect of a constant decrease in the number of those engaged in producing any foodstuff, while the number of consumers steadily grows, is already evident in our markets. We exported last year 68,000,000 bushels of wheat, which was about 30,000,000 bushels more than we had to spare. We drew down our supplies to that extent, and the market responded with the highest prices known for many years. Last May wheat that had been shipped from Kansas City to Chicago and sold there was resold and shipped back to Kansas City at an advanced price. In the same month wheat was taken out of storage in New York City, shipped by steamer to Galveston and sent by rail to supply the immediate needs of mills in the wheat belt. This season there will be an unusual wheat crop, probably 700,000,000 bushels or upwards. At 6½ bushels per capita for home consumption and seed, this leaves us a surplus of 115,000,000 bushels. We shall probably export 125,000,000 bushels, under the pressure of foreign demand, leaving us nearly as badly off as we were last year.

With our annual increase of over 1.5% in population from natural causes and immigration that has not been less than three-quarters of a million any year since 1902, there will be from 2 to 2½ million more mouths to feed every year. Having in view this increase in population, the declining average yield per acre of cultivated land in the United States after it has been farmed for a few years, the rise of per capita consumption, with a higher cost of living and the movement of the working population away from the land, the time is now approaching when we shall not only cease to be a wheat selling nation, but will find it necessary to import a portion of what we consume.

Last year the value of our total exports classified as foodstuffs, either crude or partly or wholly manufactured, and food animals, amounted to $438,000,000. We imported of the same classifications nearly $329,000,000. The idea that we feed the world is being corrected, and unless we can increase the agricultural population and their product, the question of a source of food supply at home will soon supersede the question of a market for our own products abroad. Up to this time other

*Condensed from an address delivered before the American Bankers' Association.

industries than agricultural would have flourished and grown amazingly in the United States without any artificial stimulus, because the large percentage of the total population engaged in agriculture furnished an adequate market. This condition is changing rapidly.

If, in a population of 100,000,000 people, which we shall have shortly, 45% are engaged in agriculture, then 45,000,000 people are calling upon the labor of 55,000,000

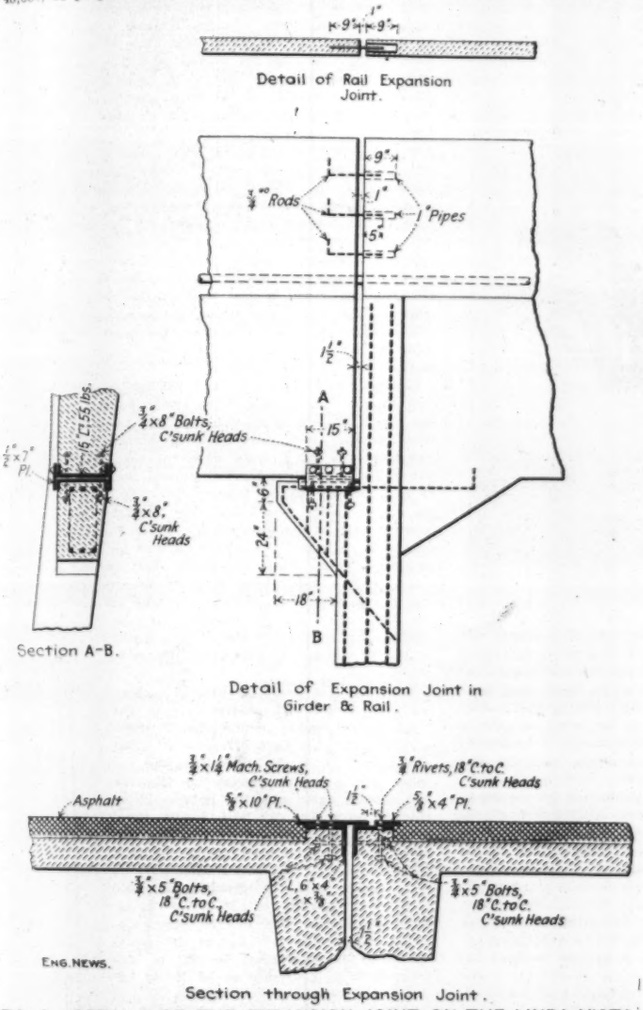


FIG. 3. DETAILS OF THE EXPANSION JOINT ON THE LINDA VISTA BRIDGE.

for clothing, professional service, commercial help, tools and furniture and all the smaller comforts and luxuries. If, instead, the agricultural percentage is reduced to 30, only 30,000,000 people instead of 45,000,000 people make such demands, while 70,000,000 instead of 55,000,000 compete in supplying them. A stationary or declining product, a soil becoming annually less productive, a revolt against the life of the farm and a consequent rise in wages amounting, since 1895, to 55.6% for ordinary day labor on the farm without board and 61.3% with board, compel such a rise of all prices as bears ruinously upon town and country alike. Our real concern is not so much to save the home market from the inroads of the foreigner as to keep it from destruction by an enlarged city life and a neglected country life, a crowded artisan population clamoring for food and a foreign demand for the product of their wages limited to fields where the competition of all the world must be met and overcome.

There are few more interesting chapters in history than those detailing the relation between industrial development, the food supply and the growth and decline of political institutions and national greatness. Civilization is mostly the story of the triumph of the human stomach in its struggle for food equal to the work of physical and mental evolution. Never yet has this enhanced cost of living, when due to agricultural decline and inability to supply national needs, failed to end in national disaster. Professor Ferrero, in his story of "The Greatness and Decline of Rome," after describing the agricultural depression of Italy, the ruin of her peasantry and the distress of all classes that followed, attributes it "simply to the increased cost of living." This, rather than imperial ambition or race decay, is the key by which history unlocks the secrets of the past.

Not only is the cultivation of the soil in the United States being neglected, but it is also notoriously ineffective. Our wheat product per acre from the older lands falls steadily. Our national average is less than half that of England or Germany, both of which have soil inferior to our own. Only by bringing rich new land under cultivation have we prevented the fall from becoming abrupt. Good farms in the Mohawk Valley in in New York State 40 years ago were worth from $100 to $150 per acre; now many are sold at from $25 to $30. This is not because wheat has become cheap, for it is dear not entirely because of Western competition, but because there is neither good cultivation nor enough cultivators. The younger generation throngs the cities, and the land, rented by its owners to tenants careless of everything but immediate profit, is abused and robbed of its fertility. In New York State 20,000 farms are for sale. If anybody imagines that this process of exhaustion and abandonment or transfer to other uses is peculiar to the East, let him look at Iowa, whose average wheat crop in the five years 1883-87 was 29,682,560 bushels, and in the five years 1904-08 was 9,976,488 bushels.

The situation, then, sums itself up thus: We have almost reached a point where, owing to increased population without increased production per acre, our home food supply will be insufficient for our needs; within ten years, possibly less, we are likely to become a wheat-importing nation; the percentage of the population engaged in agriculture and the wheat product per acre are both falling; at the same time the cost of living is raised everywhere by this relative scarcity of bread, by artificial increase in the price of all manufactured articles, and by a habit of extravagance which has enlarged the view of both rich and poor of what are to be considered the necessaries of life.

What we must come to—and the signs of the times indicate that we cannot make head in that direction too rapidly—is the smaller farm, with a more intensive agriculture. But the education of a whole people in right methods of tillage is a stupendous task. It took England nearly 50 years to do this, with powerful agencies at command and with a control over her farmers through leasehold conditions that no one in this country possesses. She has raised her average wheat yield from 12 and 15 to upwards of 30 bushels per acre. If it should take us 50 years, we would by that time probably have doubled our population also, and barely kept pace with our necessities. But we have not yet accomplished the mere preliminaries of such a process.

There are between six and seven million farms in the United States to-day. Their annual product of over $8,000,000,000 could be doubled without adding anything to the labor or money now expended. The average wheat yield of the country is now about 14 bushels per acre in good years. The same land might produce 30 bushels if properly cultivated. The average cotton yield is about four-tenths of a bale per acre, and possibly four times that amount could be raised as easily. The same holds true of the whole list of farm products.

While much praise is due to what is now being done, and well done, by the agricultural experiment stations and colleges, by the Department of Agriculture and by farmers' institutes and other agencies, the job is too big for them. When we set out to educate the children in the public schools, we do not establish one or two large ones in each state and expect them to go there. The farmer is almost as numerous, as much in need of instruction, and is as unable to leave home in search of it or to absorb it through literary channels, as the child. The education must be taken to him. If all the graduates of all the agricultural colleges were sent out as missionaries to the farm, there would not be enough of them to do the work. But it is the sort of work in which every state should engage without delay.

What has to be taught is not abstruse. While high-grade farming can furnish employment for the best intelligence, instruction in a few simple subjects will enable the ordinary farmer to double his product. He needs to be taught how to prepare a field properly for the seed; how to select and where to get the seed that will yield the best return; how to cultivate each crop; how to combine stock-raising with tillage, and how to rotate his crops and preserve unimpaired the richness of his soil. On his own farm, with the material and the object lesson before him, under instruction that comes with public authority and sanction, he will be a pupil apt to learn. It is on a par with the importance of the public school. We have not yet made a beginning; but every other interest and every other item of proposed legislation might well wait until we do.

The eminent historian to whom I have already referred, scanning the history of more than 2,500 years with the eye of the philosopher, determined to extract from this vast store of facts, according to the modern scientific method, some fixed principle in the affairs of men, announces this as his conclusion: "The only durable conquests, even in ages of barbarism, are conquests made by the plow."

If this was true of the rude ages when men lived for the sword, and the tiller of the earth was either a slave or a still more wretched peasant, it is far truer to-day when civilization has built her imposing fabric upon the expected bounty of the earth. We must maintain, protect and extend these conquests by which the race has won its way. It is not, as in the old mythology, Atlas whom we see groaning beneath the weight of the world upon his shoulders, but the homelier and humbler figure of the cultivator of the soil. It is for each of us, in every capacity, public and private, to do what in us lies to enlighten, reinvigorate and sustain this common benefactor of our kind.

A Traveling Laboratory Case for Use in Water Analyses.

We give below a concise description of a traveling laboratory case for use in sanitary studies of water-supply. The case was designed by Dr. H. W. Hill, Assistant Director of the Minnesota State Board of Health Laboratories. The description is taken from Bulletin 154, U. S. Bureau of Plant Industry (Washington, D. C.) and is as follows:

The traveling laboratory case is a box made of half-inch pine, 18¼ ins. long, 6¾ ins. wide, and 10¾ ins. high, outside dimensions. The front opens on strap hinges at the base. The top is supplied with a comfortable handle and opens on strap hinges at the back; it carries a hinged iron strap, which engages with a staple on the front and is secured with a padlock. The box is treated inside and out with aniline black, and the corners are protected by trunk shoulder plates.

A half-inch horizontal partition divides the box into two sets of compartments. The lower set consists of three compartments 8 ins. high and 6 ins. deep; two of these, adjoining, are 5 ins. wide; the third is 6¼ ins. wide. The 5-in. compartments each carry ten Petri dishes, which are wrapped in filter paper before sterilization to exclude dust and to prevent breakage in transit. The third compartment carries a Barthel alcohol lamp, and inverted over the lamp is a copper dish (4 ins. in diameter, 5 ins. high), for boiling water to melt agar media, and a tripod for supporting the dish on the stem of the lamp. A small bottle for extra alcohol and one or two towels also fit into this compartment. The upper set consists of one large compartment 6 ins. deep, 7 ins. high, and 10½ ins. wide, and a small one 6 ins. deep, 7 ins. high, and 6¼ ins. wide. The small compartment carries six cylindrical 4-oz. glass-stoppered collecting bottles and two rectangular 5-oz. rubber-stoppered bottles for sterile dilution water. The large compartment contains two wooden test-tube racks, supported by vertical guides at the ends, and constructed of ¼-in. pine, as follows: From the center line of a flat wooden base (1½ ins. wide and 10 ins. long) rises a flat sheet of wood (5 ins. high and 10½ ins. long); narrow vertical strips of wood at each end of each side of this sheet coapt with the vertical guides on the ends of the compartment, leaving a narrow edge of the ends of the sheet exposed to slide in the slots of the guides. Two pins in each vertical strip permit rubber bands to be stretched across each side of each sheet from end to end. The test tubes are inserted between the sheet and the rubber bands on each side of the sheet, resting on the wooden base. Each rack carries about twenty test tubes. The floor of this compartment next to the back of the box is cut away along its whole length for a width of 1⅛ ins.; through this opening pass pipette cases containing two thermometers and about twenty pipettes, four pipettes to a case. Between the racks is space for an envelope containing gummed labels, spare elastics, a lead pencil, a glass pencil, etc., and cards for recording data on samples collected.

A High Powered Locomotive Pile Driver Carrying Its Own Turntable*.

By WALTER FERRIS,† M. Am. Soc. M. E.

The machine described in this paper is of some engineering interest as the most substantial and complete railway pile driver yet produced. Its special claims to consideration as a new development in mechanical engineering, however, lie in the unusual arrangement and strength of the self-propelling mechanism, and in the self-contained hydraulic turntable, whereby the entire machine, including trucks, is quickly lifted clear of the rails and turned end for end. The propelling engines, mounted on the car body and delivering more than 250 HP. are connected to the axles of ordinary bogie trucks on the opposite side of the swinging frame balances the weight of the leaders, keeping the machine always in a stable condition. In this position a pile can be driven 19 ft. from the center of the track. Fig. 4 shows the machine standing on its hydraulic turntable with all the wheels in the air. In this position and without any blocking the pile was picked up, put in place in the leaders and driven at a distance of 32 ft. from the center of the track. It was not desirable to drive this pile all the way in and the leaders were therefore backed down to clear the partially driven pile. The principal use of the hydraulic turntable, which will be described later on, is to turn the machine end for end when there is no railway turntable or "Y" available.

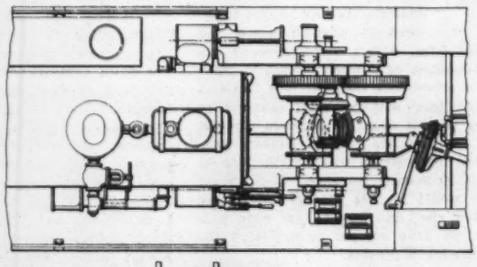
Fig. 2 shows the general arrangement of machinery. The car is 40 ft. long, built entirely of structural steel and steel castings. On the front end is mounted the swinging frame, shown in Figs. 1, 3 and 4, consisting of a pair of parallel trusses supporting the leaders at one end and a counterweight at the other end with the necessary parts for raising and lowering the leaders and swinging the entire frame to the right or left at right angles to the car body. This frame is swung by a large worm wheel, which also serves to raise and lower the leaders.

FIG. 1. LOCOMOTIVE PILE DRIVER; LEADERS IN SHIPPING POSITION.
(Self-contained, hydraulic turntable is shown under center of car.)

without interfering with the movements of the trucks in turning curves, passing over frogs, and the like.

The machine was designed to meet the requirement of the Atchison, Topeka & Santa Fe Ry. system for a pile driver capable of climbing any grade on their line and hauling its own cars of piles, tools, etc. The self-propelling pile drivers built hitherto are capable of moving themselves for short distances while at work, but from lack of sufficient steam capacity as well as engine power must have a locomotive in constant attendance. The services of this locomotive are usually charged against the bridge department of a railway at the rate of from $20 to $30 per day. After having used several of the ordinary self-propelling machines, A. F. Robinson, Bridge Engineer of the Santa Fe system, prepared specifications calling for a pile driver of much higher propelling power. This resulted in the designing by the Bucyrus Co. of the machine herein described, which has been in active service on the Santa Fe lines since January, 1909.

The general appearance of the machine is shown in the illustrations. Fig. 1 shows the machine with leaders folded in shipping position. Fig. 3 shows the leaders up ready for driving with the swinging frame turned across the track, and also shows how the counterweight



The latter operations are accomplished by means of the long worm-wheel hub projecting upward through the center pintle upon which the swinging frame revolves, a double-grooved sheave or drum being keyed to the upper end of the worm-wheel hub. This drum is provided with a clutch by which it can be engaged with the main base plate of the car body. This frame is swung by a large worm wheel, which also serves to raise and lower the leaders.

The latter operations are accomplished by means of the long worm-wheel hub projecting upward through the center pintle upon which the swinging frame revolves, a double-grooved sheave or drum being keyed to the upper end of the worm-wheel hub. This drum is provided with a clutch by which it can be engaged with the main base plate of the car body. When this clutch engages with the swinging frame the latter moves with the worm wheel. When the clutch is out of engagement, however, and a brake is applied between the car body and the swinging frame, the revolution of the worm wheel does not carry the swinging frame with it, but merely turns the drum, which is keyed to the worm wheel. The ropes leading from the drum to either end of the revolving frame are so arranged as to raise or lower the leaders. The details of the worm wheel, drum, clutch, etc., are clearly shown in Fig. 5. This figure also shows a large circular base plate on the car, for supporting the weight of the revolving frame. The latter is provided with four conical rollers which run upon the finished upper surface of the base plate.

From Fig. 2 it may be seen that the leaders are mounted on a leader-raising frame by means of a pivot near the center of the leaders. A screw and nut device takes hold of the leaders some distance below the pivot and with this they can be inclined either to the right or left so as to drive batter piles. The arrangement for raising and lowering the leaders acts directly upon the raising frame, which is carried by two rolling bearings A which roll on the top of the upper chords of the swinging frame, while the radius arm *B* takes hold of the lower end of the raising frame, causing it to move in the arc of a circle as indicated. The ropes *C* and *D* over the drum pass around suitable idler sheaves and are anchored to the sliding crosshead *E* forming a closed circuit. From this crosshead the raising arms *F* take hold of the raising frame, transmitting the movement of the crosshead to the latter. The hammer-hoist rope, pile-hoist rope and steam pipe (the last-named is not shown) run up from the car body to the swinging frame through the large hollow hub of the swinging worm wheel. The steam pipe is on the center and the ropes are so close on either side that they work equally well with the leaders in any position with regard to the car body.

The main engines are 11 ins. × 12 ins. with Stephenson link motion. From the crank shaft the two drums for the pile-hoist and hammer-hoist lines are geared in the usual manner with cone friction clutches. The engines, however, are much more powerful than would be required for these drums. The propelling gearing consists of two inclined shafts leading from the crank shaft of the engine to the rear axle of the forward truck and the forward axle of the rear truck. From Fig. 2 it will be seen that each of these shafts carries on its upper end two bevel gears, while the crank shaft carries a sliding sleeve with a small bevel gear on one end and a large one on the other end, the two meshing respectively with the two pairs on the inclined driving shafts. By sliding the sleeve to one end or the other a fast or slow propelling ratio is obtained.

With the fast gear, on level or moderate grades and with moderate loads, the machine can readily be driven at 25 miles per hour and has been driven at 30 miles per hour. With the slow gear the engines are powerful enough to slip the two driving axles and thus obtain all the tractive force that can be had with about 80,000 lbs. weight on drivers. The machine can thus be used effectively as a switching engine and will readily haul its own weight with considerable additional load over grades of 1½% or more. The acceptance test of the first machine built was a run of 32 miles up a grade averaging 75 ft. to the mile, with a maximum of 97 ft. to the mile.

The lower ends of the inclined propelling shafts shown in Fig. 2 are provided with bevel pinions. These pinions mesh with bevel gears cast in one piece with large sleeves, as shown in Fig. 6. These sleeves surround the driving axles, a cored hole through the middle of the sleeves 10 ins. in diameter providing about 2 ins. clearance around the axles. The sleeves are supported by brackets rigidly attached to the car body with babbitted bearings. All this gearing is fastened to the car body only and remains in line without regard to the swivel-

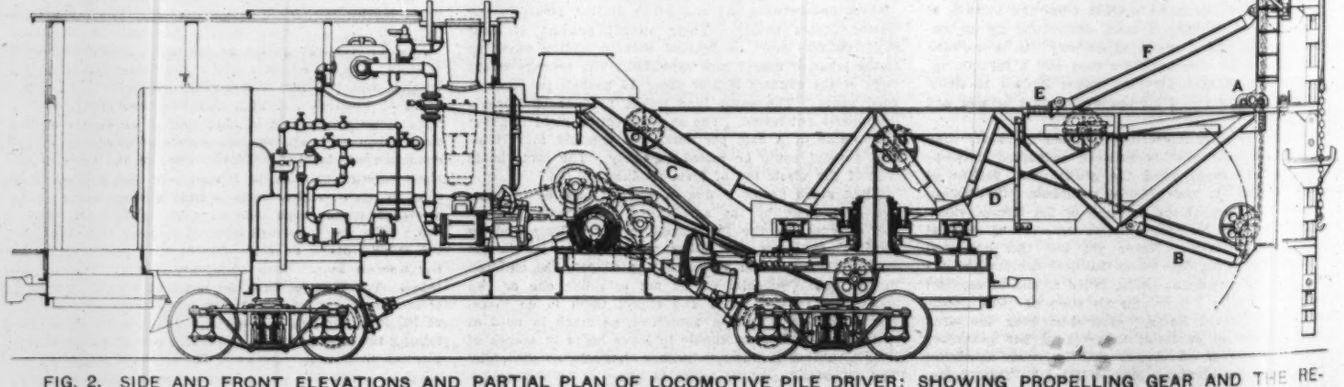


FIG. 2. SIDE AND FRONT ELEVATIONS AND PARTIAL PLAN OF LOCOMOTIVE PILE DRIVER; SHOWING PROPELLING GEAR AND THE REVOLVING FRAME.
(The hydraulic turntable is omitted in this figure.)

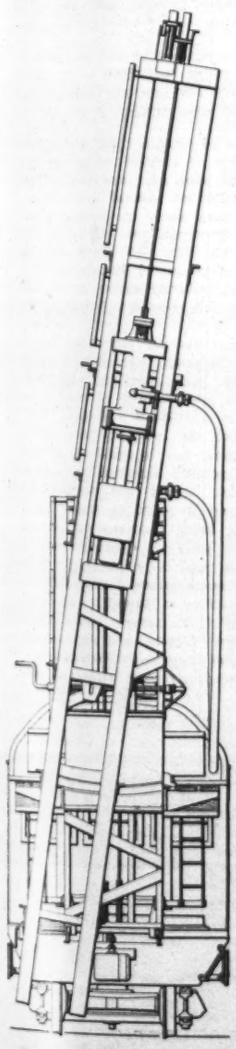
*Reprinted from the "Journal" of the American Society of Mechanical Engineers for November, 1909.

†Assistant Chief Engineer, Bucyrus Co., South Milwaukee, Wis.

ing of the trucks. The connection by which the driving torque is communicated from the propelling sleeves to the axles is also shown in Fig. 6. It consists of a modified type of universal joint so arranged that there is nothing to interfere with the axle passing through the middle. The propelling sleeve carries at one end a large flange with lugs supporting two pins *G*; these pins engaging with two bronze bushed lugs *H* formed on the inner side of the toggle casting *I*. On its outer side it carries another pair of lugs *J* on an axis at right angles to the axis of the pins *G* and these lugs *J* are connected to a U-shaped driving yoke *K*. The open end of this yoke is again pin-connected to a bracket *L* which is keyed to the axle.

Both pins, *G* and *M*, are made much longer than the lugs which engage them, to permit end play due to the displacements of the axle, as shown on the plan view in Fig. 6. As these two pin axes are at right angles to each other their combined slip will take care of any movement of translation, while the combined revolution of the parts around the pins *G*, *M* and *N* provides for any possible twisting. The wearing parts involved are six steel pins and six bronze bushings, all of the same size, and all parts are so made that the wearing surfaces can be replaced without taking the truck from under the machine. The pins are made hollow and are packed for continuous lubrication.

The method of detaching the driving gears when it is desirable to ship the pile driver in a freight train is indicated in Fig. 2, at the rear axle of the front truck, where an operating lever is shown taking hold of the bearing which supports the bevel pinion at the lower end of the forward driving shaft. This bearing and the pinion are mounted in a sliding support, which enables the pinion to be drawn out of mesh with the bevel gear, permitting the propelling sleeves and gears shown in Fig. 6 to revolve freely with no gears in mesh. The same arrangement is provided on the rear truck. In order to provide the necessary steam capacity for these propelling requirements, the boiler required is nearly three times the size of those ordinarily furnished for pile drivers. The boiler is of the locomotive type, 54 ins. in diameter, 15 ft. 9 ins. long, having about 800 sq. ft. of heating surface and designed for 175 lbs. pressure. This pressure is required only for steam economy on propelling runs, as the engines are so large that all the ordinary movements of the machine can be made with 100 lbs. pressure.



This jack consists of two ball-race castings having races about 5 ft. in diameter provided with 2-in. steel balls. The upper ball race is carried through the pins *R*

One of the striking features of the machine is the hydraulic turntable, which is shown in action in Fig. 4, and in shipping position in Fig. 1. It is frequently very important that a pile driver should be able to turn end for end or else to work at either end indifferently. The latter plan requires that the boiler and pile-driving machinery shall all be mounted upon a swinging deck, which can be turned through a full circle and reach either end of the car. This plan has been thoroughly tried and is satisfactory as far as pile driving is concerned, but makes it impossible to get a sufficiently powerful and reliable propelling gear between the engines and the trucks. In the new machine, therefore, the pile-driving apparatus is mounted on the car body where it can work at one end only, thus obtaining the powerful propelling drive already described. To reverse the machine the hydraulic lifting jack shown in Fig. 7 is attached underneath the car and under the center of gravity of the entire structure.

upon a set of four bell cranks or levers *O*, two on each side of the car, the bell cranks being pivoted upon brackets *P* attached to the main car beams. The upper ends of each pair of bell cranks are connected by a parallel rod, while the rear bell cranks on the two sides of the car are connected across by a heavy shaft *Q*. This arrangement compels all four bell cranks to act in unison, and when they are operated by the hydraulic cylinders the four pins *R* from which the upper ball race is suspended move up and down the same distance, maintaining the turn table at all times parallel to the car, even though the center of gravity may be quite a distance away from the center of the turntable.

The system of bell cranks is operated by a pair of hydraulic cylinders 12 ins. in diameter, having about 28-in. stroke. One cylinder is located on each side of the car. The cylinders have trunk pistons with sufficient area between the outside of the trunk and the bore of the cylinder to provide force enough on the return stroke to raise the turntable away from the track and put it in shipping position. While lifting the car the pressure acts upon the full area of the 12-in. piston. The working pressure of about 200 lbs. per sq. in. is provided by the boiler feed pump.

The lower ball race, which is suspended from the upper ball race, by suitable clips, is provided with a set of chair castings which rest on the rails and can readily be placed under the four jack screws, which are located in the four corners of the lower ball race. The lower ball race also carries a circular rack, while the upper ball race has a transverse shaft with a crank on each end and a double gear reduction to a swinging pinion which meshes with the rack on the lower ball race. When the machine is to be turned it is necessary only to put the chair castings *S* under the jack screws and run the latter down until they touch the chairs. The entire car is then raised by pumping water into the hydraulic cylinders and turned end for end by hand, two men working on each crank. In a high wind three men may be required on each crank. The entire turning operation occupies from 10 to 15 mins. An important incidental advantage of the turntable has already been touched upon in the third paragraph. Fig. 3 and Fig. 4 show its use to enable the driver to reach a pile at a long distance from the center of the track. In this way, should occasion arise, any point within 32 ft. of the track may be reached and the pile driven.

The tests made since the first machine was put in operation indicate that it will fully come up to expectations. The first machine was built with slow gear only, having a maximum speed of 15 miles per hour. The results of its test on grades have already been mentioned. It has since been in constant use on the western divisions of the Santa Fe and on heavy grades. The fast propelling gear herein described has now been added and two machines thus equipped have been built and shipped. On one of these, built for the Canadian Pacific Ry., the following speed test was made. The machine hauled an ordinary passenger car from South Milwaukee to Racine and return, a distance of 12.6 miles each way. The run to Racine was made in 31 minutes, an average speed of 24.4 miles per hour, two miles being made at a speed of 30 miles per hour. The return run was made in 37 minutes, making an average speed of 20.5 miles per hour.

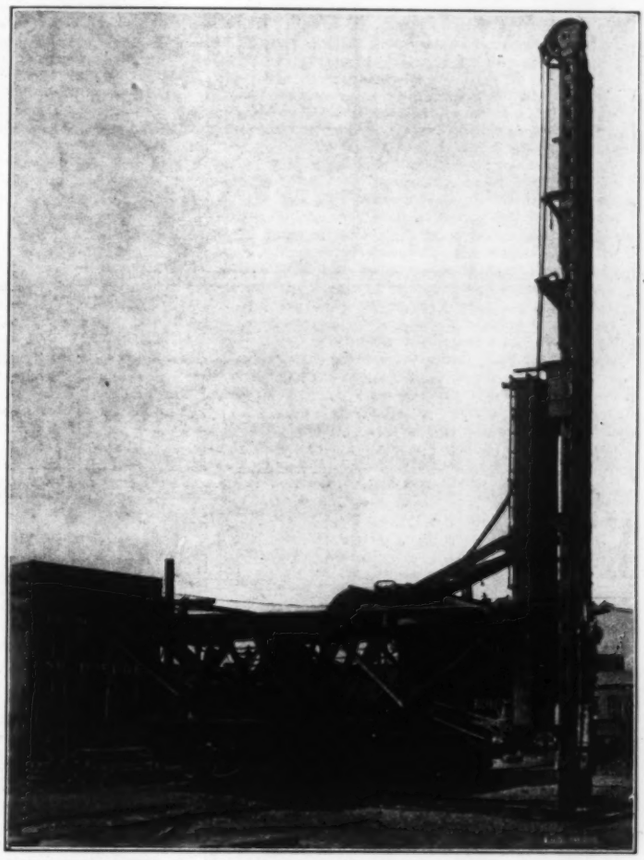


FIG. 3. LOCOMOTIVE PILE DRIVER; NORMAL WORKING POSITION.

The shipping weight of the machine without the turntable, as shown in Fig. 2, is about 147,000 lbs.; with the turntable, as shown in Figs. 1, 3 and 4, about 160,000 lbs. It is equipped with either a No. 2 steam hammer or a 3,500-lb. drop hammer, or both. The leaders are

FIG. 4. SELF-CONTAINED TURNTABLE IN ACTION; PILE DRIVER TURNED AT RIGHT ANGLES TO TRACK WITH BOTH TRUCKS OFF THE GROUND.
(In this position a pile can be driven at a distance of 32 ft. from the track.)

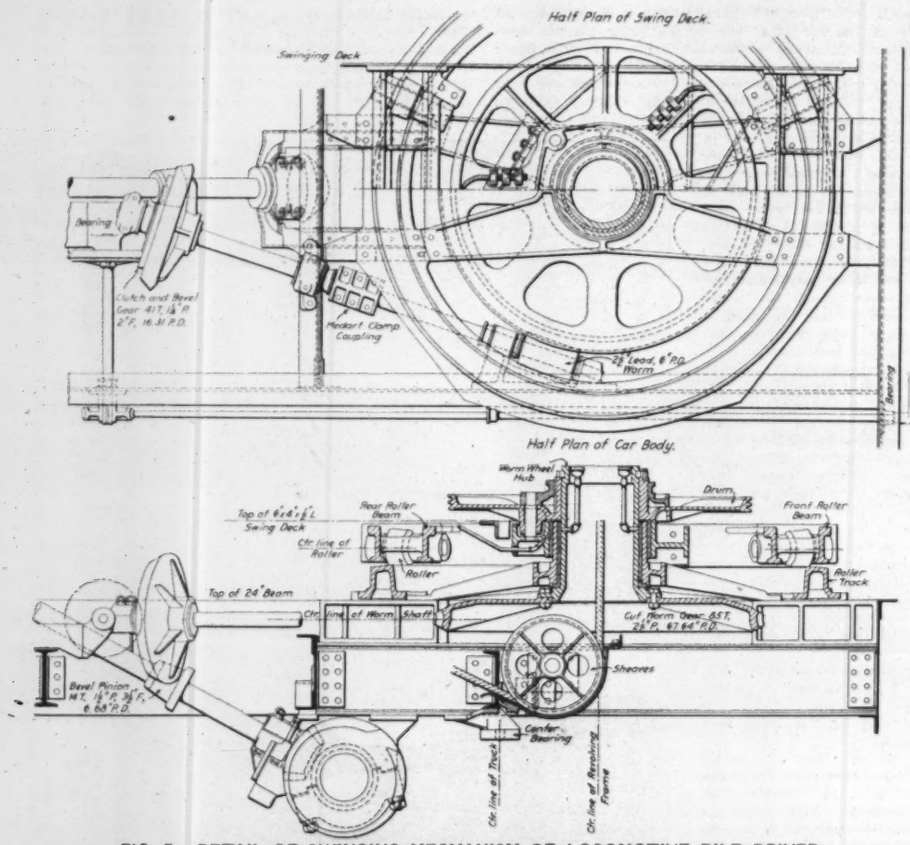


FIG. 5. DETAIL OF SWINGING MECHANISM OF LOCOMOTIVE PILE DRIVER.

(The hand swinging mechanism, consisting of crank, shaft, worm-wheel and bevel gear, shown in the half plan of car body, has been found unnecessary and is not used on the later models. Bearing of bevel pinion at lower end of propelling shaft is shown incorrectly in this figure; see Fig. 3.)

so made that either hammer can be used without change. The reach for driving piles is 18 ft. ahead of the center of the forward wheel, or 19 ft. on each side, as already mentioned; while with the turntable, 32 ft. on either side can be reached. The leaders are 40 ft. long. The construction is entirely of metal, except the house.

Notes on High Tension Transmission Lines in California.*

By S. L. FOSTER.†

In California are found some of the longest transmissions, the highest voltages, and at the same time some of the best and some of the worst electrical conditions. Much that is of vital interest here is only of historical interest, or perhaps incredible to engineers east of the Rocky Mountains. Much that interests those of the east is valueless here.

We have no sleet or snow loads, no sleet nor snow driving or accumulations, no tornadoes, and practically no tree or lightning interferences such as are met with in the east.

For high-tension station outlets we simply build ordinary terra-cotta sewer pipes (bell ends inside) into the walls, set a circular perforated disk of plate glass in each bell end, and lead the wire through the center of the 2-in. or 3-in. hole in the plate, having thus ample clearance and ample insulation. The hole aids station ventilation. There is no snow to fear, and the upward tip of pipe toward the inside of the station obviates danger from rain. In later 60,000-volt work a 24-in. square of glass with a central 3-in. hole for the conductor is used, and the terra-cotta pipe feature omitted, as birds sometimes build nests in them. Lightning arresters are usually conspicuous by their absence, as are also the effects of lightning.

As compensation for these advantages, however, we have in some parts of the country eagles, wild swans, pelicans or blue herons with over 6-ft. spread of wings, that occasionally short-circuit even 72-in. spaced wires. We also have from four to six months of rainless weather during the summer, when the dust becomes prevalent. In addition, along the coast and bays we have spells of heavy fogs at night.

The combination of dust, fog and night wind applies a conducting smear over the insulators, the pins, the cross-arms and the poles of our high-tension lines, that results in most unexpected and extraordinary phenomena to disturb the electrician's equanimity.

One effect appears in the fact that in a few, though important, localities a voltage test factor of safety of six in the insulator is inadequate to secure continuous operation. Another is the fact that the brush discharge from insulator to wood pin generates nitric acid from the nitrogen of the air and the hydrogen and oxygen of the fog or air. This nitric acid attacks and "digests" the threads of the wood pin top until it becomes a powder, and the thread ceases to serve as a support.

As the surface of the pin, where unprotected by the insulator, is covered with the moist paste of [illegible] dust and fog drops, it is a better conductor than the protected part of the pin, and is not attacked at [illegible]. On the drier and more highly resisting part of the wood pin, up under the insulator, the heat generated by the leakage current appears first, but as the moisture is dried out of the other surfaces the evidences of heat appear, and pins, cross-arms and pole tops suffer.

Brown striation marks on pin, arms and pole, charred "worm holes" in pins, wood pins burned off altogether, leaving insulators adrift in the air, cross-arms charred or entirely burned off around the iron pin or at the gain in the pole, are some of the strange symptoms of this disease.

The "static" or "brush discharge" or "corona," as it is variously called, cracks and snaps between insulator and pin by day and scintillates by night.

*All these interesting manifestations occur on a [illegible],000-volt, 25-cycle, three-phase line, 24-in. spacing, equipped with porcelain two-part insulators tested by the author to 50,000 volts, and advertised by the maker as "test voltage 70,000."

Of course, these eccentricities do not occur every day nor continue all the day when they do occur. In fact, they cause very few interferences with our city 13,000-volt service, but to one accustomed to the prosaic behavior of the insulator on the 500-volt d.c. work they are interesting, and keep us guessing.

The cause of the burn-offs at the pole is a natural query, and various theories have been advanced. At first, the two ¾-in. galvanized-iron machine bolts holding the cross-arm to the pole passed through the pole, as was the classical practice derived from the eastern lag-bolt custom. After much trouble from fires in cross-arm gains during foggy weather, it was felt that it would be an improvement to do away with these through bolts and substitute a U-bolt that would go around the pole. This is now standard practice, and the author has heard of no cases of fires in cross-arm gains where the U-bolt construction has been installed.

In the early 60,000-volt, 150-mile transmission construction the single three-wire circuit was constructed at the points on an equilateral triangle, apex up, using a single cross-arm and setting one wooden pin into the top of the pole.

In the fog district even a spacing of 42 ins. between conductors and insulators, tested to 120,000 volts, failed to be infallible on the 60,000-volt line, and fires started around the "kingpin," and even further down on the pole.

The theory was advanced to explain these phenomena that there were certain paths of varying conductivity in or between the fibers of the wood pole, and that in this star-connected line with grounded neutral the potential tended to force current along these conducting paths, and as the moisture was evaporated the persisting current caused heating and the fire. To break up this action by breaking the uninterrupted course of these paths, the pin was removed from the center of the pole and mounted on a short one-pin cross-arm bolted around the top of the pole.

The wood pins had been "digested" seriously in the "fog belt" by the "brush discharge," and were replaced by hollow galvanized iron pins provided with lead-threaded tops. These wood pins referred to were made of eucalyptus or Australian blue gum, which is stronger than the locust or oak usually furnished in pins, and is equal to hickory. The wood is specially seasoned and treated for this purpose. Sawed into stocks 3 ins. square, the wood is boiled in water for 24 hours, thereby being deprived of its sap. These pieces of wood are then arranged for efficient drying, and so exposed for three months. After being turned to shape, the finished pins are boiled in linseed oil at a temperature of 100° C. for several hours, the oil penetrating about 1/16-in. and serving as a protection against moisture. When new in the laboratory these pins readily withstand a 60,-

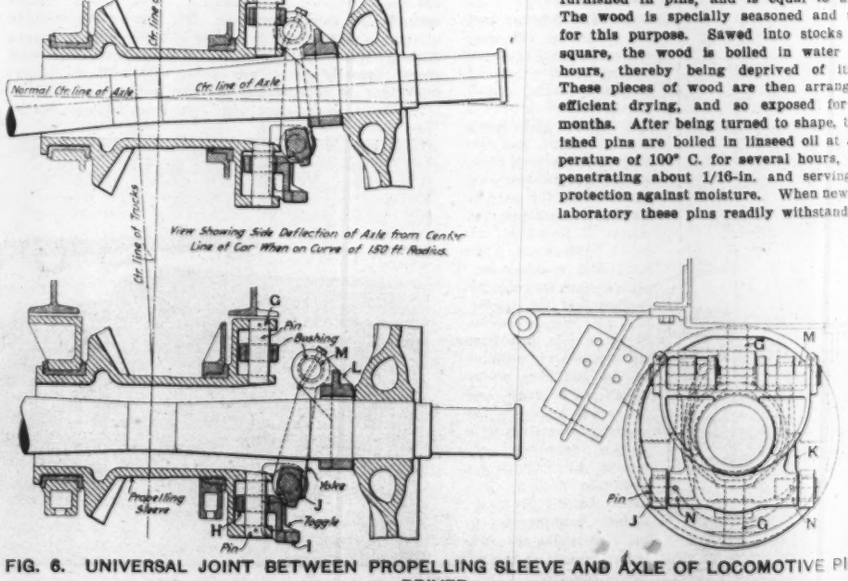


FIG. 6. UNIVERSAL JOINT BETWEEN PROPELLING SLEEVE AND AXLE OF LOCOMOTIVE PILE DRIVER.

(Transmission is through bevel gears and the joint is necessary to prevent trouble on curves.)

*An appendix to the report of the Committee on Power Distribution, presented at the annual meeting of the American Street and Interurban Railway Engineering Association at Denver, Colo., Oct. 4 to 8.

†Chief Electrician, United Railways of San Francisco, San Francisco, Cal.

000-volt test from end to end. Thus there seems to be no ground for a claim that thorough work was not done on the wood pins.

The form of construction just described represents about the last steps in constructing combustible or perishable high-tension overhead work. The next step is to the steel tower, the steel cross-arm and the suspended insulator.

Efforts to make wooden pins answer in high-tension work here have all failed, as is evidenced by the array of iron pins now on the market, and the practice on the latest transmission projects. The day of the wood pin is practically over on the Pacific coast.

The 13,000-volt line referred to was built in 1902, after observing the difficulties of an 11,00-volt, 60-cycle three-phase line, that with 24-in. spacing and wood pins could not succeed during the foggy weather with triple-petticoat glass insulators, which have been used successfully on a 44,000-volt line in Utah. This new San Francisco line has about 4,000 insulators, 20 miles total length of pole line, 82 miles total length of conductor—0000, 000 and 00 copper, some 0000 solid, some stranded (no advantage found so far in use of stranded wire), equilateral-triangle arrangement apex up, no transposition, no cross-arm braces, no line lightning arresters.

Poles.—Square, sawed, planed, tapered red-wood poles, 50, 60, and 70 ft. long; cut from the hearts of young trees, 16 × 16 ins. at butt, 10 × 10 ins. at top, set 6 ft. deep in concrete; with galvanized-iron step irons. In the suburbs some 35-ft. and 40-ft. poles were used.

Cross-Arms.—Clear Oregon pine (similar to the Norway pine of the east), 4 × 6 ins., bolted to gained poles originally by 2¾-in. through bolts, but on latest work and in case of burned off cross-arms by ¾-in. U-shaped galvanized bolts passing around the pole. In this climate all ironwork on poles, such as lag screws, bolts, braces, steps, etc., is galvanized by the hot-dip process to prolong life and to prevent streaking with rust.

When a cross-arm burns off, if there are two triangular circuits on the pole top, a new arm is substituted for the burned one, as it always burns off at the gains, and instead of two through ¾-in. machine bolts a ¾-in. U-bolt is used on the new arm. If there be but one circuit on the two cross-arms, arranged in a triangle on one side of the pole, the three wires are simply transferred temporarily to the other side of the pole to the sound part of the arm, as the arm in this single circuit work always burns off at the pinhole nearer the pole and leaves the part of the arm in the gain sound. In each case, lead pin tops are substituted for the digested wood ones, and new insulators substituted for the old ones.

Pins.—On straight line work composite pins were used, consisting of ⅝-in. galvanized wrought iron carriage bolt, threaded wood top and truncated conical porcelain base.

The nitric acid formed by the brush discharge has "digested" many of these threaded oak tops, and as opportunity offers or necessity requires, they are replaced by threaded lead tops. When from "digestion" or burning of wood top of pin it seems necessary to take some action, a threaded lead top is substituted for the threaded wood top without washing, wiping or changing the insulator. No recurrence of similar symptoms on identical poles has been recorded, either where cross-arms have been burned or wood pin tops digested. Another company, profiting by our experience, did not attempt to use the wood tops, but retained the rest of the parts of this composite pin, cementing the bolt into the insulator with litharge and glycerine.

The brush discharge occurs during very heavy fogs between lower insulator petticoat and iron pin, just the same as when the wood top was used, but so far (four years) with no serious results.

The theoretical explanation of this performance of burning wood top on a composite pin was given in 1903 by Mr. Philip Torchio.* It is that the iron pin and the porcelain insulator, when held apart at a certain difference of potential, would act as a condenser with the air as the dielectric between them. When the wood pin top is inserted it makes the conditions of those of several condensers in series, and produces a lack of uniformity in the distribution of the e.m.f. between line wire and iron pin, raises the voltage between porcelain and pin, and, assuming that the potential before the wood top replaced the air as dielectric was the critical point, causes the brush discharge and the charring of the wood. The wood non-conducting tip would thus seem to be a distinct disadvantage, and the conditions would be improved by replacing it by a tip of conducting material, lead, for example.

In place of the perforated pyramidal porcelain base, experience would seem to advise a thoroughly threaded bolt provided with nut and washer both below and above the arm to furnish ample area of contact for the dissipation of this unwelcome "static." Cross-arms sometimes burn off around through insulator bolt, and this has been believed to be due to the looseness of the bolt, caused by the charring away of the substance of the wood top and the reduction of the pin's long dimension by the iron bolt being forced through the arm by the weight of conductor and insulator crushing down the charred wood top and leaving nut and washer of bolt hanging free of contact with lower surface of arm. On a foggy night, besides the purple ring of fire along the edge of the inner petticoat of the porcelain insulator, a pretty "corona," or halo effect, or diminutive "aurora" effect, is seen around the edge of this washer at the bottom of the pin. Accompanied by a distinct hum and an unmistakable odor of ozone, a circle of short, beautiful electric emanations or uninterrupted series of discharges can be seen going apparently from the edge of the iron washer to the wood cross-arm.

For corner work a 1⅝-in. galvanized iron pin is used, cemented into the insulator with a mixture of litharge and glycerine. These ingredients are mixed on a glass plate with a putty knife to a stiff paste. The pinhole of the upturned insulator is filled to the proper height and the pin pressed into place, being held central in the hole until the compound sets, by wooden wedges. Pins thus cemented are usually allowed to stand for 24 hours before being used, though this setting depends on the weather. In rainy weather 24 hours is not long enough. In dry weather haste must be used lest the cement set before the pin can be inserted.

These pins are only roughened at the ends going into the insulator so as to hold the cement. At the other end they are threaded so as to permit of a nut and washer going both below and above the cross-arm.

Insulators.—The insulators generally used are a two-petticoat, brown porcelain, umbrella-top insulator. When building this 13,000-volt line it was specified that the insulators should pass a 50,000-volt brine test. All that were accepted (about 80% of the shipment) passed this test, which consisted of inverting the insulator in a metal pan of brine connected to one pole and putting a wire in the brine-filled inner petticoat connected to the other pole of the testing set. To-day the manufacturers advertise these insulators as "test voltage 70,000."

With two of these in series, each having 13 ins. of creepage distance between conductor and pin, it was felt that the construction was safe from leakage, but we were disappointed. The 20% that were punctured in the testing made the makers feel so badly that they now insist on the insulators being tested at the factory before shipment.

The "static" or "brush discharge," or "corona" that

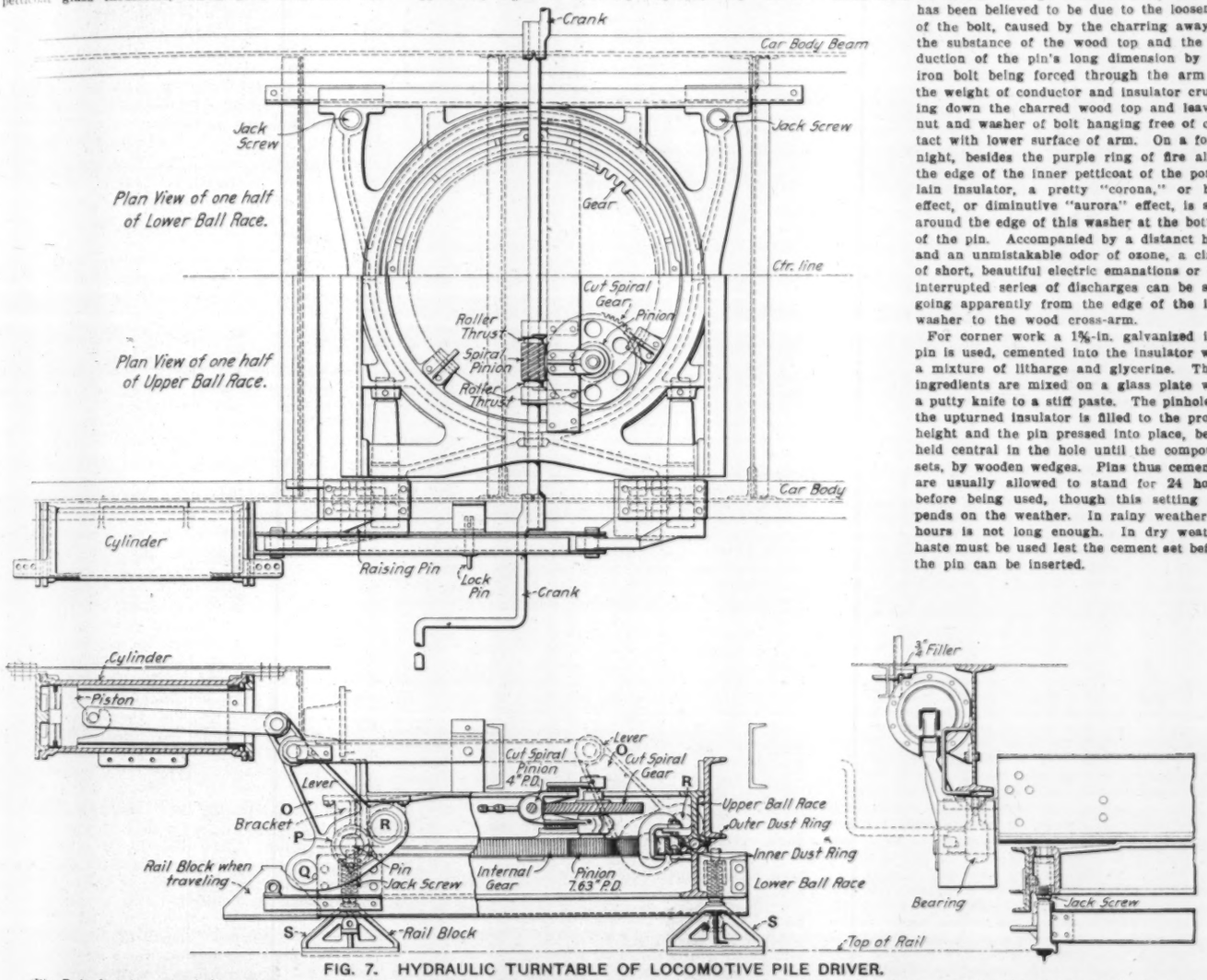


FIG. 7. HYDRAULIC TURNTABLE OF LOCOMOTIVE PILE DRIVER.

(Pin R is fast to upper ball race of turntable; pin P is held by a bracket attached to car-body beam; Q is a shaft making levers on both sides of car act in unison. Car body beam is omitted in the side elevation.)

*Proceedings of the American Institute of Electrical Engineers, 1903, p. 293.

is active in certain localities during six months, or during our summer months when sea fogs are prevalent, "digests" some of the wood tops of our composite pins as stated. It has led in a few cases to burned-off pole tops, where the cross-arm was fastened to the pole by bolts passing through both. A small red hot coal appears at the cross-arm gain, and in the steady night wind this is soon fanned to a busy flame. The first case reported was attacked with a piece of burlap—no use; then sand was tried—equally unsuccessful; then the current was cut off, and the fire was extinguished with water and the night's run finished, the arm and insulator being changed the next day. U-bolts around the pole are now used instead of through bolts.

One day a policeman reported the top of a high pole on fire. The substation was called: "no trouble on the line." A representative hastened to the location and found a fire engine just leaving, with the fire out. These firemen had actually played water from their house on that pole top fire with six 13,000-volt wires on the cross-arms and had received no shock. This happened at about 8 a. m., and after the unusual bath the lines continued to work normally till 1 a. m. the next morning, when the cross-arm and insulators were changed. There was no disturbance whatever from the fire or hosing felt at the power-house or substations.

Some engineers in testing insulators use the spray test. In the "fog belt" out here we would like to have a spray on all our insulators all the time. In the winter, when we have long spells of continued rain, we have no insulator trouble at all. During the summer the fog and dust form a conducting paste that at some points leads to all the peculiar exhibitions previously detailed. As soon as the first rain of winter has washed off this paste the troubles vanish for six months. So far, no evidence has been reported of the lead-pin tops or cementing being affected by this "static."

When the fog is persistent and the action gets serious, we stop it readily enough by washing the insulators with ordinary water inside and out, but without removing them. It is expensive and slow work washing insulators in the cold wind and fog at night on the tops of 50-ft. poles, but in certain exposed locations and during particularly severe stresses of foggy weather it is the only remedy. Washing is more effective than wiping. Sometimes the paste forms a plating or enamel that cannot be removed entirely by even gasoline. It has never occurred the second time on the same pole, and usually starts on a pin that is on the lee side of the pole, away from the direct blast of the fog-laden sea breeze.

In the beginning there were four types of porcelain insulators in use, all having passed the 50,000-volt test, but since the number has been reduced to one, there has been but one burned-off pole, that resulted in an interruption to the service, out of 1,000 poles in six years, and this one occurred on a pole standing 15 ft. from a chemical factory. There was more than one burn-off, but the others occurred, fortunately, either on a duplicate line or near the regular shutting-down time.

When the fog is absent it is marvelous how little porcelain is required to insulate one wire from its neighbor. During our recent strikes, or due to malicious boys, two adjacent insulators have often been seen with the outer petticoat in both cases entirely gone, and yet there was no evidence of trouble, and they were left undisturbed till shutting down time.

The best defense against this fog and dust action is a generous insulation factor of safety in the insulator (say, make a test voltage six times working voltage), which should always be of porcelain, as being less hygroscopic than glass and tougher. If this fails, the last resort is the cloth and the water pail at night.

Of course falling tree limbs, the busy small boy with his piece of wire, or the malevolent striker with his chain have burned off our line a few times, but so far without injury to persons or property. Much of this would be prevented by having had the three wires of the line arranged with the apex of the triangle down.

One power company in San Francisco goes farther, and besides arranging the three wires on an inverted equilateral triangle plan, extends light galvanized iron channel irons along the line of the ends of the cross-arms and 3 ft. beyond. A guard wire is stretched along the tops of these upward projecting points.

Some of the lines arranged on the apex down plan offer an attractive roost for eagles and hawks. When the bird stretches his wings for his final hop into space he short-circuits the two wires, and incidentally kills himself.

Precautions During Work.—When making repairs, even if assured by the station men that the current has been cut off, the linemen always hang an iron chain over the three wires to prevent the current coming on again without warning. No lineman has ever been injured on our 13,000-volt lines.

Switching.—All our arc-rupturing switching is done in the power-house or substation by means of oil switches. There are installed, for convenience in cutting up the lines for repairs, two double sets of double-break, triple-pole, horizontal swing-knife switches, but it is never intended to open these when the main current is flowing.

Corners or Turns.—At corners or turns in the pole line, care was used to secure simple yet safe work. The angle made by the line wires at each turn was bisected exactly by the cross-arms. As the poles were of square section and sawed truly from base to top, a triangular flat template was furnished the linemen to set against the curbstone. By bringing the side of the pole against the proper side of the template the cross-arm was automatically located along the line bisecting the angle made by the wires.

In the first construction, in order to attain a factor of safety of 13 with the use of eucalyptus or Australian gum-tree wood pins, which were the standard here in 1902, three insulators were used at each turn, and as the outside pins were but 12 ins. c. to c. it was specified that the special insulators to be used for corners should not exceed 6 ins. in maximum outside diameter.

The San Francisco fog paste proved to be too much for these insulators, and two insulators are now used of our standard type, cemented over our standard wrought-iron 1⅝-in. galvanized copper pin, giving a factor of safety of about 60 in the pin when using 000 copper conductor. This method of making the turn has a neat appearance and is economical in the use of cross-arms, insulators and labor.

Of course, if the same spacing between pins is maintained on these corner cross-arms as on the straight line arms, the conductors are brought nearer together at the corner poles by the difference between the standard spacing and the product of this spacing and the sine of half this included angle bisected. By spacing the pins on the corner arms a distance equal to the quotient obtained by dividing the standard spacing by the sine of half the bisected angle the conductors can be kept equally distant at all points. This refinement is not often necessary in our work, as the poles carrying the high-tension wires were also used to support the trolley span wires, and have the usual spacing of from 100 to 120 ft. In the case of 24-in. pin spacing and 135° turn the spacing at the cross-arms between the wires is 22.17 ins. By spacing the pins 26 ins. on the corner arms the conductors will be kept 24 ins. apart.

In the original use of three insulators per wire on one set of cross-arms at what would be a 135° turn on a single insulator, the symmetrical arrangement of these three insulators is secured when there are angles of 165° made in the conductor at each insulator.

The digging of holes was done by shovels, bars or dynamite, according to whether the material to be excavated was sand, clay or rock. Some of these 50 and 60-ft. poles were piked in, some were hoisted in by a portable "gin pole" with hinged base mounted on a low truck along with a double-geared winch, using as gin poles the 30-ft. 5-in., 6-in. or 7-in. standard pipe iron side poles, which were to be replaced by the taller poles.

The other methods of completing the line contained nothing different from standard practice. The last six years' experience has taught us how to construct and how to maintain our high-tension lines so as to escape the interesting effects of fog and dust.

The results, summed up, are as follows:

1. There should be a larger factor of safety in test voltage of insulators to be used in the foggy localities than elsewhere, say six.
2. To keep the insulators up to a safe margin these insulators should be wiped or washed once a year in the most aggravatingly foggy locations.
3. The through bolts for attaching the cross-arms should be replaced by the U-bolt around the pole.
4. The all-wood pin or the wood tipped iron pin should be replaced by the all-iron pin with the threaded lead top.
5. No pin should be located in a hole bored in the top of the pole, but should be installed on a short arm bolted to the pole by a U-bolt.
6. All iron parts should be galvanized.
7. An insulator with few "still air spaces" is preferable to one with many such spaces, no matter what the comparative "test voltage" may be.
8. If wood pins are used, very many will surely burn off during the foggy conditions. If iron pins are used, a few cross-arms may burn off. In any case the main dependence must be on the insulator.

THE NEW HARBOR WORKS AT DOVER, ENG., have just been completed and opened for service. This is one of the largest artificial harbors ever constructed, especially in respect to the masonry piers and breakwaters. In general the new works comprise an enclosing breakwater surrounding 610 acres of harbor, in which a 2,300-ft. pier and shore quays furnish unloading space. The breakwater itself is made up of three parts, one arm 2,900 ft. long, another 4,200 ft. long and a final pier 2,900 ft. long, all built of large concrete blocks founded on a bottom in some places 49 ft. below low water. In all there are 74,000 concrete blocks on the works, totaling 1,500,000 cu. yds. of concrete and about 70,000 cu. yds. of granite for facing blocks. The harbor is the design of Messrs. Coode, Son & Matthews and the contract was executed by Messrs. S. Pearson & Sons, Ltd.

Some Detail Tunnel Costs in Tunnel No. 7. of the Los Angeles Aqueduct.

By C. H. RICHARDS.*

The appended study covers unit costs of driving a timbered tunnel in the Little Lake division of the Los Angeles Aqueduct [William Mulholland, Chief Engineer; J. B. Lippincott, Asst. Chief Engineer; Edward Comerer, Foreman in Charge; and the writer, Engineer in Charge of the Division,] during the 15-day period from Aug. 15 to Aug. 29, inclusive. The figures relate to the north heading only.

During this period 90 ft. were driven in 15 eight-hour shifts. The tunnel is approximately 10 × 10 ft. in section and contains 3½ cu. yds. in place per lineal foot to pay line. The over-break-age was about 17%, making a total of 0.4 cu. yds. of broken material per foot of tunnel.

The heading is 800 ft. in from the portal. It is lighted by electricity at 110 volts, and ventilated by a No. 3 Champion Blower through 12 in. pipe, the heading being cleared in fifteen minutes after shooting.

Drilling is done by one No. 7 Leyner drill, water being forced through the hollow steel. This drill used approximately 66 cu. ft. free air per minute at 83 lbs. pressure, drilling holes to 10 ft. in depth.

Mucking is facilitated by steel sheets laid down before shooting. The muckers use No. 3 D-handle square-point shovels. Dirt is hauled away in 32 cu. ft. rocker dump cars pulled by a 3½-ton locomotive running on a single 24-in. gage track laid with 25-lb. steel.

The rock is a close-grained hard gray granite with numerous seams, causing the drill to run from alinement, but it breaks well. The seams and water combined make it necessary to timber all of this ground. The ground carries enough water to make disagreeable mucking, and to require pumping.

The timbering comprises sets of 6 × 8 in. Oregon pine, spaced 5 to 8 ft. apart, as ground permits, and 2 × 6 lagging. Each set consists of two vertical posts and a four-segment arch.

The crew consisted of one shift boss at $3.50 per day; four miners at $3.00; five muckers at $2.50, and one trammer at $2.50. The blacksmith doing repair work was paid $4.00 per day.

The four miners worked on day shift, drilling the ground, timbering and shooting. The muckers followed on night shift. This arrangement resulted in a clean heading for the drill crews, and nothing interfered with the mucking crew.

The cost of work during this 15-day period is tabulated below in detail.

To explain the table further the following particulars are noted as to drilling and powder.

DRILLING.—During the 15-day period 150 holes were drilled, aggregating 1,202.3 ft. in length; the average depth of hole therefore was 8 ft. The average speed of drilling was 21.74 ft. hole per hour of actual drilling time, or 15.84 ft. per hr. if lost time is included. This means that the average hole (8 ft). was drilled in 22 mins. The fastest hole, however, was 9 ft. 6 ins. drilled in 10 mins., while the slowest was 8 ft. 6 ins. drilled in 78 mins. The average cost of drilling per foot of hole was 3.6 cts., as given in the table.

EXPLOSIVES.—There were used 650 lbs. of 1⅛-in. 40% gelatine; 250 lbs. 1-in. 40% gelatine; and 150 lbs. 1-in. 60% gelatine; a total of 1,050 lbs. This is 11.66 lbs. per lin. ft. of tunnel, or 3.3 lbs. per cu. yd. place measurement. The cost (delivered) was $140.87. Adding the cost of fuse (2,700 ft. $13.85), caps (306 = $2.49), and tamping stick ($0.48), makes the total cost $157.69, which is about $0.50 per cu. yd. place measurement and $0.27 per cu. yd. loose.

The following summarizes the above cost together with the field and office charges assessable to the work. Attention may be called to the fact that the figure $12.165 given as direct charge differs from the previous total of $13.667 by the amount ($1.502) charged for tracks, the latter being included in the previous detail tabulation. In the recapitulation this auxiliary charge is reduced

*Division Engineer, Little Lake Division, Los Angeles Aqueduct, Narka, Cal.

by the estimated amount of salvage on the track material.

RECAPITULATION OF UNIT COSTS.

Class of charge.	Cost per foot of tunnel, dollars.	
Direct Charges:		
Labor	$7.056	
Material and Supplies	4.399	
Local Administration and Engrg.	0.56	
Live-stock service	0.15	
		$12.165
Auxiliary Charges:		
Labor on tracks, etc.	$0.468	
Material for tracks, etc.	1.034	
	$1.502	
Salvage on material about 66%	.69	
		0.812
*Roads and Trails**		1.50
*Buildings**		0.20
*Water Supply**		0.22
*Machinery and Tools**		1.06
Total Field Charges		$15.957
Add 3% for Executive Office Administration		0.475
Total Cost of Tunnel, Timbered and Ready for Lining, per lin. ft.		$16.432

*The total cost of these works on the entire division, apportioned to the several parts of the permanent construction, gives as estimated charges per foot of this tunnel the figures noted.

TABLE OF UNIT COSTS OF TUNNELING AND TIMBERING.

(North Heading of Tunnel No. 7, Little Lake Division of Los Angeles Aqueduct.)

For 15-day period, Aug. 15-Aug. 29, 1909; advance, 90 ft.

Class of work.	Totals for 90-ft. length. Labor Hours.	Labor Cost.	Cost. lin ft. tunnel.
LABOR—			
Inside Labor:			
Squaring heading	23.5	$9.03	$0.10
Setting up and tearing down machine (1)	36.	16.59	.184
Drilling, incl. time of shift boss (3.6 cts. per foot of hole.)	55.33	43.21	.48
Blowing out holes	5.75	4.15	.046
Loading and shooting	56.25	22.31	.248
Mucking (412 cars)	835.	268.44	2.98
Trimming, stulling, caves, &c.	102.	39.24	.436
Timbering ($11.32 per M.)	107.25	40.82	.453
Lost time	40.75	15.66	.174
Bonus (30 cts. per man per ft. over 2.3 ft., per shift)	.....	112.08	1.24
Repairs to trolley, pump, etc.	3.25	1.2	.013
Totals, Inside Labor	1,265.08	$572.73	$6.354
Outside Labor:			
Sharpening steel (with Leyner No. 2 machine)	44.	17.83	$0.198
Repairing drill	7.5	2.88	.032
Framing timbers at shop ($2.42 per M.)	.....	8.75	.097
Light and power	90.	33.75	.375
Totals, Outside Labor	141.5	$63.21	$0.702
Auxiliary Labor:			
Laying track, 90 ft.	31.5	$12.75	$0.141
Drainage line, 90 ft.	43.5	14.33	.16
Ventilation line, 72 ft.	11.	3.44	.048
Trolley line, 95 ft.	18.	6.35	.067
Air line, 80 ft.	2.5	.80	.01
Water line, 80 ft.	2.5	.79	.01
Lights line, 90 ft.	8.	2.86	.032
Totals, Auxiliary Labor	117.0	$41.32	$0.468
Local Administration & Eng'r'g:			
Proportion of Division Engineer and Assistant's time		$50.40	$0.56
Total Labor Cost		$727.66	$8.084

	Total cost.	Cost per lin ft. of tunnel.
MATERIAL—		
Construction Material and Supplies:		
Drill repairs ($0.018 per ft. hole.)	$22.47	$0.25
Drill supplies; oil, steel, coal ($0.008 per ft. hole.)	9.41	.104
Mucking supplies; oil, etc.	.73	.008
Power and lighting current (4,207 KW.-hrs., at 1.7 cts.)	71.52	.795
Explosives; powder, fuse, caps, etc. (11.66 lbs. powder per ft. tunnel.)	157.09	1.752
Timbers, wedges, dowels, nails, etc. (3,597 ft. B. M. = 40 ft. B. M. per ft. tunnel.)	122.16	1.36
Lighting (candles $8.59, el. lt. globes $3.09)	11.67	.13
Totals, Construction Material	$393.65	$4.390
Auxiliary Material:		
Trackage; 25-lb. rail, ties, etc.	$21.11	$0.235
Drainage; 2-in. pipe and el. wire	7.87	.087
Ventilation; 12-in. pipe (for 72-ft.)	29.24	.405
Trolley; wire, etc. (for 95-ft.)	9.75	.102
Air line; pipe, etc. (for 80-ft.)	7.25	.09
Water line; pipe, etc. (for 80-ft.)	7.25	.09
Lights line; wire, etc.	2.22	.025
Totals, Auxiliary Material	$84.64	$1.034
Total Material Cost	$480.29	$5.433
LIVE STOCK—		
Mule, 15 days, at 90 cts.	$13.50	$0.15
Total Direct & Auxiliary Field Charges.	$1,221.45	$13.667

Methods and Cost of Working in the Red Rock Tunnel During a Month of Record Advance.

In our issue of Sept. 9 we had the pleasure of recording a remarkable performance in tunneling, the Red Rock tunnel of the Los Angeles Aqueduct establishing during August a new high record for speed of heading advance. This record was made, as it now appears, in rock so soft that augers could be used, and it is therefore not strictly comparable with hard-rock tunneling performances. On the other hand, it is the maximum speed record for any class of tunneling whatever, and must be ranked as a most excellent achievement.

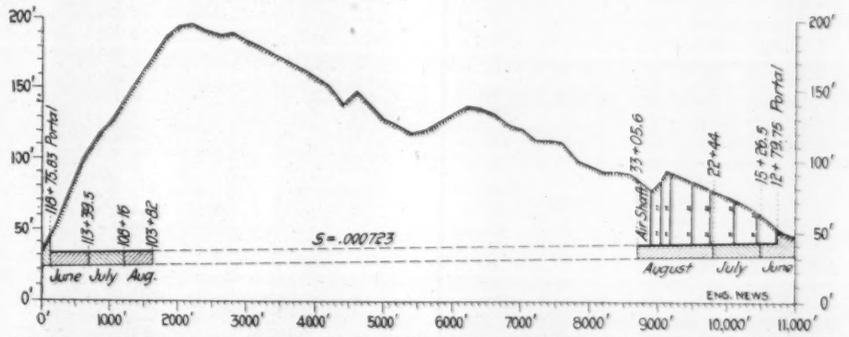


FIG. 1. PROFILE OF TUNNEL 17 M (RED ROCK TUNNEL) OF THE LOS ANGELES AQUEDUCT.

Such a high-pressure performance required very efficient methods of working, of course, and an ambitious working force. In reply to our inquiries for details, Mr. J. B. Lippincott, Assistant Chief Engineer of the Los Angeles Aqueduct, has sent us a full statement, reprinted herewith.

The Red Rock tunnel, known as 17 M on the Los Angeles Aqueduct, is situated about 35 miles northeasterly from the town of Mojave, Cal. The total length of the tunnel is to be 10,956 ft. The material has been geologically classified as a sandstone. It is soft enough to permit of boring with augers, but hard enough to stand without timbering.

The profile and finished section of the tunnel are shown in Figs. 1 and 2. The design was made for a tunnel that is higher than usual for the given area of cross-section, in order to reduce the span of the roof, and to permit of driving a lower heading and subsequently excavating the upper portion of the tunnel from movable platforms which are moved thereunder. The material from the upper heading is shot down onto the platform, and loaded from the cars through a trap, the platform being high enough to permit of the cars passing beneath it.

The tunnel was being driven during July on a two-shift basis, but on Aug. 3 it was decided to place three shifts in the heading to see what distance might be made during the month, and the relative cost. During the month 91 eight-hour shifts were worked. The regulation mining crew consisted of one shift boss, five miners and four muckers, and this number was not exceeded during the month.

DRILLING AND MUCKING.—Three miners were kept at work driving the heading, putting down holes with augers (hand steel being used occasionally). Two-inch holes were driven. Their grouping is given by Fig. 3. Four muckers were used in loading the cars, and the other two miners were used in trimming the tunnel to a finished section, and shooting down the upper heading from 40 to 50 ft. back of the face. These men erected the movable platform.

In this case, as in practically all cases where rapid progress is being made, the greatest problem consisted in the removal of the muck. On this work, three mules and drivers were used on each shift, and switches put in the tunnel at sufficient intervals to permit the cars to pass to advantage. Side rocker dump cars, 32 cu. ft. capacity, were used.

The average length of the holes was 6 ft., and the effort was made to shoot two rounds per shift. This was done with the exception of one night, Aug. 31, when the tunnel was flooded with water.

The explosives used were 40% Dupont ammonia dynamite and black powder. The center cut hole was usually sprung with the 40% powder and then loaded with black powder. The average amount used was 4.2 lbs. of 40% ammonia dynamite and 2.2 lbs. of black powder per foot of tunnel driven.

COST.—The total distance run during the month was 1,061.6 ft., the cost distribution being as follows:

SUBDIVISION OF TUNNELING COST, RED ROCK TUNNEL.

	Per lin. ft.
Pay of tunnel labor	$3.14
Bonus of tunnel labor	1.43
Blacksmith and general labor	.26
Shaft, for ventilation	.21
Live stock	.24
Material and freight	1.13
Total cost per ft.	$6.41

The preliminary report showed a cost of slightly less than $6 a foot, but the final cost report on this work is as given above.

VENTILATION.—This portion of the tunnel ranges from 40 to 50 ft. beneath the surface of the ground, and ventilation was obtained by stoping up air shafts to the surface. It has been found that the gases resulting from the explosion of ammonia dynamite are not very noxious, it being possible to return to the heading inside of 20 to 60 minutes after the shooting without serious results to the men. Consequently, little trouble was experienced with delays from smoke.

The August run began 964 ft. from the north portal. An equipment of electric locomotives and Roots positive blowers such as are being used in a number of tunnels on the aqueduct, is now (Oct. 1) being installed in order to handle the transportation and ventilation problems, which become more serious as the distance in from the portal is increased. This equipment was not available during the month of August. The power to operate this machinery is furnished by hydro-electric plants which have been built by the city of Los Angeles on streams on the eastern face of the Sierra Nevada in the Owens Valley, this power being transmitted to this and other portion of the work along the line of the aqueduct. The aggregate length of these power lines which have been built for construction purposes alone is 205 miles.

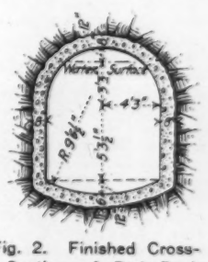


Fig. 2. Finished Cross-Section of Red Rock Tunnel.

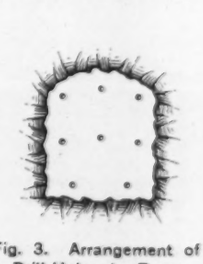


Fig. 3. Arrangement of Drill-Holes in Face.

BONUS SYSTEM.—On the aqueduct work, an estimate is made by the engineers of a reasonable rate of progress per shift in each tunnel,

and this is considered the base rate. A bonus is paid to the miners for any excess in footage attained. In the case of this tunnel, the base rate was placed at 4 ft. per shift, and the bonus paid per man per foot per shift is 25 cts. The work is measured each ten days, and the bonus paid for these intervals. Those sharing in the bonus are the tunnel foreman, the shift boss, miners and muckers. All back trimming and timbering must be done by the crew sharing in the bonus. Only men who work continuously during the ten-day periods are entitled to bonus, except when the work is suspended owing to causes over which the men have no control. The amount of bonus earned by the men during the month of August was about $55 per man. The credit for the inauguration of this bonus system is directly due to the Chief Engineer, Mr. Wm. Mulholland, and has proved successful, both as to economy and progress.

FLAGS FOR RECORDS.—Monthly reports are sent out to all engineers and superintendents showing the unit cost and the amount of work accomplished by all the different camps. In addition, record flags are presented to the crews holding the best records for different classes of work, and these flags are transferred when the records are beaten by other crews.

It has been found that the men engaged in tunnel driving often enter into the spirit of the work as athletes enter into a contest, and this is stimulated by the additional financial compensation which they receive. This is largely responsible for the big tunnel runs that have been made on the aqueduct.

The division engineer in charge of the Red Rock tunnel is Mr. A. C. Hansen, and it is due to his personal supervision, coupled with the enthusiasm of the men over the effort they were making to obtain a record, that this run was made. The tunnel as completed was in good shape, and entirely satisfactory, being trimmed neatly to line and grade.

A VERY LARGE BLAST was shot on Aug. 31, 1909, by the Southern California Water Co. in a hill of granite rock at Morena, Cal., about 65 miles east of San Diego. The company is now engaged in the construction of a large dam, for which the rock obtained from the shot is to be used. It was intended to make a first blast from which 50,000 cu. yds. of material would be obtained and then to make another to furnish more rock, but the first shot brought down about 120,000 cu. yds. of rock so that the second was unnecessary. A tunnel was first driven into the face of the wall for a distance of 125 ft. and at an elevation about 140 ft. below the level of the top of the hill. From this tunnel two short side drifts were driven and filled with the powder, a total charge of 33,550 lbs. of Champion powder, 2,000 lbs. of 60% dynamite, and 3,400 lbs. of 40% dynamite, a total of 38,950 lbs. The side drifts and the tunnel were then filled with tamped earth and rock to a point 20 ft. from the mouth of the tunnel, and the blast fired. The work was under the charge of Mr. M. M. O'Shaughnessy for the Water Company and Mr. A. H. Crane, of the Du Pont Powder Co.

PANAMA CANAL WORK during the month of October totaled 2,827,798 cu. yds. of excavation, 41,650 cu. yds. of concrete deposited and 553,594 cu. yds. of fill placed in dams, for 26 working days. This is an average daily excavation of 108,761 cu. yds., which is lower than any recent record, but the rainfall during the month was 17.16 ins., quite considerably above any recent amount, even in a rainy season month.

A Duplex Channeling Machine for Rock Cutting.

A recent development in rock-cutting machinery is a duplex channeling machine having two gangs of cutters which are under the control of one operator and are arranged to strike alternate blows, thus balancing the movements. The rock channeler is a well-established machine for quarry work and for the excavation of canals, locks, wheel-pits, etc., in solid rock. By its use the shattering of the rock sides is avoided, and the breakage of valuable quarried rock is reduced to a minimum. The ordinary form of machine has a single cylinder mounted on a standard and with a gang of cutter bars attached to the crosshead on the piston rod. This apparatus is mounted on a platform traveling on small wheels, so that as the machine advances it cuts a slot or channel in the rock. It is handled by a runner in much the same way as a rock drill except that the latter is stationary.

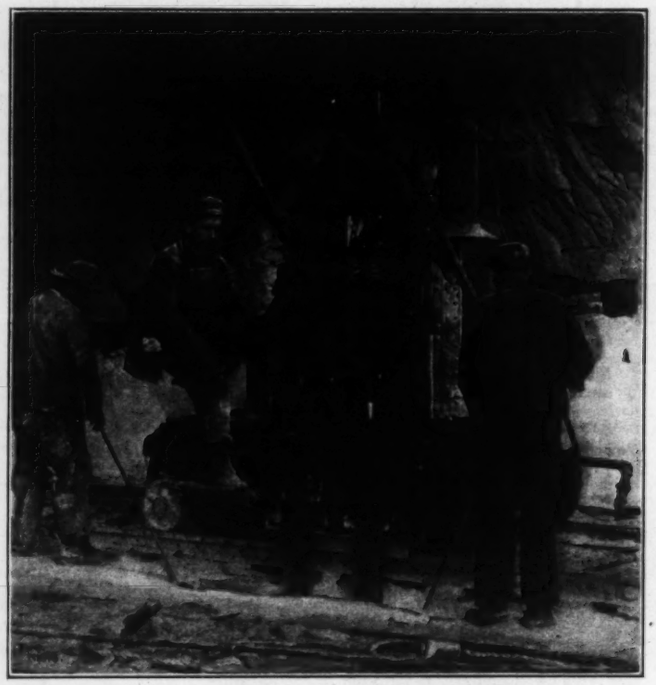


FIG. 1. DUPLEX CHANNELING MACHINE, OPERATED BY COMPRESSED AIR (EQUIPPED WITH A REHEATER.)
(Sullivan Machinery Co., Chicago, Ill., Manufacturer.)

A few years ago the Georgia Marble Co. tried the experiment of mounting two channelers on one car or platform, the machines acting independently but working in the same cut or channel, and being controlled by the one man. The results were such as to lead the company to convert its single-head into double-head machines, thus practically doubling its capacity without increasing the number of men employed. The double-head machines were built by the Sullivan Machinery Co., of Chicago, and this company has developed the duplex machine as a marked improvement upon the former. In this new arrangement the two cutting engines are mounted on a single standard, and equipped with a valve gear so arranged that while one gang of cutters is making the down stroke the other is making the return stroke.

An important advantage over the double-head machine is in steadiness of working and decrease of vibration. With the independent double-head arrangement, the two engines may get "out of step," striking simultaneously instead of alternately, thus causing the machine to rock and to throw the cut out of line. Special care is required on the part of the runner to keep the two engines in step, and maintain the cut in a direct line, and this puts a check on the rapidity of progress of the work. With an irregular cut there is liability of binding of the cutters, and consequent excessive wear and tear on the machine. With the duplex arrangement, the runner operates it as a single machine, the alternate action being effected automatically by the valve gear. By means of a lever, however, the runner can stop either engine and continue work with the other, and as each cylinder has its own cushion valve, this change in working does not impose any abnormal stress on the machine. This feature is of value when starting a cut or in working through a mud seam, to protect the front

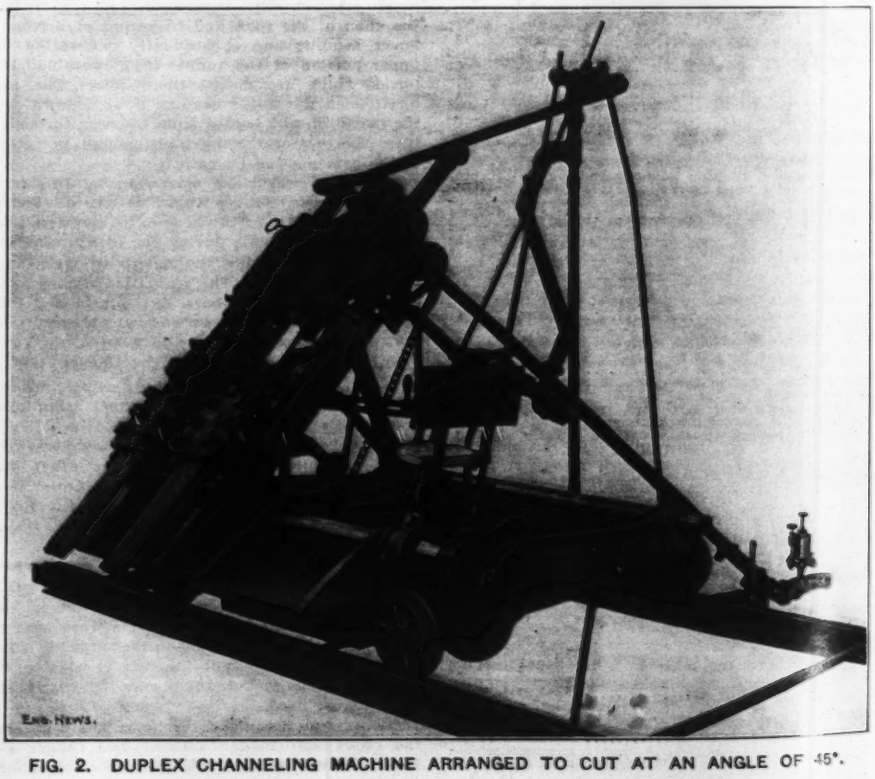


FIG. 2. DUPLEX CHANNELING MACHINE ARRANGED TO CUT AT AN ANGLE OF 45°.

heads from damage by heavy shocks. The force of the blow of each cutting head can be regulated independently by a cut-off valve to suit the conditions of the work.

The machine is handled as easily as an ordinary single channeler, owing to the convenience and simplicity of its controlling devices. As the reduction in vibration reduces any tendency of the machine to work out of line, the track need not be wedged and braced as rigidly as is required for the ordinary machines. This in turn reduces the delays in shifting track, and adds to the actual working time, which is a special advantage when working short lengths of cut.

The feeding mechanism is operated by a sprocket chain drive operated by a friction clutch on the shaft of the feed engine. At the end of a run, this mechanism serves also to raise the cutting heads to the top of the feed screw. This effects a saving of time in changing cutters, and a saving of labor in operating the machine.

While the weight of the duplex machine is greater than that of the single machine, special means are provided to facilitate the shifting of the track. Two screw jacks are permanently attached to the rear of the frame, and when the machine has reached the end of the track these are used to raise this side of the machine clear of the rail. The cutters are then fed down so as to raise the front of the machine. The track is shifted ahead, and the machine lowered upon it ready for another advance.

The machines may be fitted with their own boilers, or may be connected to steam or air pipes laid through the work. The machine shown in Fig. 1 is operated by air and is equipped with a reheater. The two men with scrapers are keeping the cut free from sludge. This machine is working in a Vermont marble quarry. The standard carrying the cylinders and heads is pivoted, so that the machine can work at any angle from the vertical to the horizontal position. Fig. 2 shows it arranged to cut at an angle of 45°. This arrangement is specially important in marble quarries, on which it is often necessary to make angle or tunnel cuts to avoid stripping great quantities of worthless rock.

In the quarry of the Evans Marble Co., at Friendsville, Tenn., the duplex machines have averaged 200 sq. ft. of channel per 10-hour day, with record runs of 350 sq. ft. at different times. The single-head machines in the same quarry and under the same conditions average only 80 sq. ft. per day. The cut is 6 ft. deep and the length of run is only 20 ft.; the increased efficiency of the duplex machines would be still higher on longer cuts. The machines are operated by steam at about 100 lbs. pressure at the throttle. The great increase in capacity over that of two single machines is due to the fact that the cutters in the duplex machine retain their cutting edge better, as double the number are employed in the same work. There is also less trouble and delay due to the sludge, owing to the alternation and greater frequency of the strokes.

The principal advantages claimed for the duplex channeler as compared with the single-head type of machines are as follows:

(1) Increase in cutting capacity, due to the use of two cutting engines instead of one.

(2) Greater smoothness in operation, with absence of jar and vibration, due to the balancing of the engine. This results in:

(3) Saving of time, and therefore diminished labor cost, and increased time devoted to cutting, because with this machine, the track does not require to be blocked up so carefully as with the single-head machines. The steady and smooth running of the machine diminishes the likelihood of jarring the track out of line with the cut, which would cause the steels to bind, with reduced cutting speed and increased wear on the mechanism.

(4) Reduction in labor cost, as only one man is needed to operate this machine, as against two for two single-head machines.

(5) The use of a power feed and a power hoist, saves time in changing cutters at the end of a run, and labor in operating the machine.

Continuous Annealing Furnaces for Small Work.*

Internally-fired rotary furnaces for heating large runs of small pieces of iron and steel were introduced a few years ago and proved useful for continuous processes of annealing or hardening various small iron or steel parts, such as rivets, bolts, nuts, washers, balls, etc. Many advantages have been found in automatic continuous heating for annealing or hardening the smaller classes of work. It has been found possible to dump the work in a hopper and feed it gradually into the revolving hearth, in such a way comes into contact with the heated gases and the hot lining. This process of heating is more rapid and uniform than when the work remains in a fixed position, where that material farthest from the entrance of the flame or covered up by other pieces of metal requires a long time, comparatively, to get to the proper temperature.

Oil or gas fuel has been used with uniformly satisfactory results. Where the work is to be hardened the discharge end of the furnace can be placed beneath the cooling bath to prevent oxidation. For annealing only, some other method has to be adopted to control the air inlet if oxidation is feared.

These furnaces, of the general design shown in Fig. 1, were built first with a special shape of brick lining which formed a deep helical chamber whose walls forced and guided the metal parts forward as the furnace revolved. This arrangement worked well with light or symmetrical short pieces, such as lock washers, balls, etc., but with the longer pieces like bolts and rivets and with irregularly shaped steel punchings, forgings, castings, etc., the results were not wholly satisfactory. It was found, for instance, that the irregular pieces would lodge and clog up the furnace. When a run of bolts had apparently stopped and balls were fed through, both balls and bolts were received at the discharge for a time.

Other means of feeding the material forward through the furnace were needed. A new type of furnace was designed for this sort of work. The rotating drum was lined with a standard refractory brick so as to give a smooth internal surface as shown in Fig. 2. The axis of the drum is tilted up to give the revolving hearth a forward inclination. The material is fed into the higher end and as the drum is slowly rotated there is a gradual forward motion of the material. By means of a hand wheel the inclination of the axis of the drum is changed to regulate the rate of forward feeding of the work to be heated and to change the time of heating.

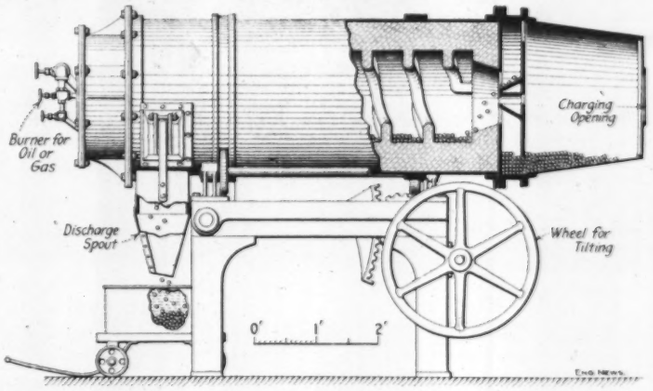


Fig. 1. Early Design With Helical Chamber.

These smooth-lined furnaces have been built in capacities up to 2,000 lbs. stock per hour. In all sizes the internal temperature can be accurately adjusted by a pyrometer and a desired value maintained constantly with no appreciable fluctuation. Uniformity of treatment of the product passed through has therefore been guaranteed. The furnaces illustrated are built by the Rockwell Furnace Co., 26 Cortlandt St., New York City.

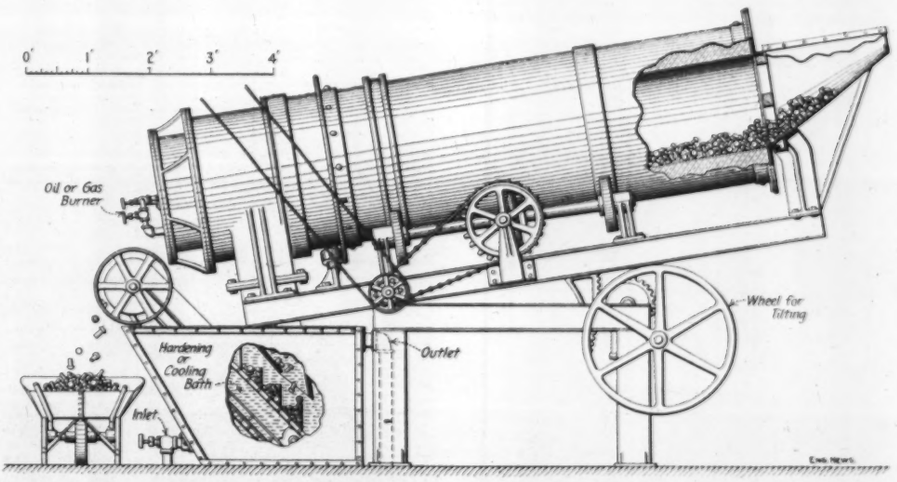


Fig. 2. New Design with Smooth Lining and Inclined Hearth.

FIGS. 1 AND 2. ROTARY FURNACES FOR CONTINUOUS HEATING OF SMALL METAL PARTS.
(Rockwell Furnace Co., New York City.)

*From information furnished by the Rockwell Furnace Co., 26 Cortlandt St., New York City.

THE LONGEST SIMPLE SPAN IN THE WORLD is a highway bridge over the Miami River at Elizabethtown, Ohio. It is 586 ft. long c. to c. end pins, being thus 30 ft. longer than the longest previous simple span. It is 30 ft. wide in the clear, or 32½ ft. c. to c. trusses. The truss outline shows a straight bottom chord and curved (parabolic) top chord, center depth 80 ft. and depth at hip 40 ft., 18 sub-panels (i. e., 7 main panels and at each end two hip panels). The floor consists of 20-in 65-lb. I-beam longitudinals along each truss, floorbeams of the same size I's at the panel-points and half-way between supported by these longitudinals, and 6-in. 12¼-lb. I-beam stringers 30 ins. on centers. The stringers are seated on corbels of short lengths of 9-in. I-beam resting on the top flange of the floorbeams. A 2½-in. oak floor nailed to spiking pieces on the stringers forms the roadway surface. The bridge was designed by H. G. Tyrrell, of Evanston, Ill. It was built in 1904.

Pneumatic Caissons on the Baltimore & Ohio R. R. Bridge Across the Susquehanna.

In the reconstruction of the long bridge across the Susquehanna River just above Havre-de-Grace, Md., on the line of the Baltimore & Ohio R. R., it was necessary to build several large and deep concrete piers to replace the old ones, of stone masonry, in the construction of which Gen. Sooy-Smith used some of the first compressed-air caissons in this country. The new piers were also sunk by this same method and the design of the caissons there used presents some novelties that makes reproduction of the details worth while. For purposes of comparison the interested reader is referred to descriptions of the original caissons in Engineering News of May 10 and Nov. 22, 1884, and Jan. 3, Feb. 7, April 11-25, and May 2, 1885, and also to the summarized description in Prof. I. O. Baker's "Masonry Construction."

The new caissons are three in number, all of the same size. The piers are of different depths, but the difference in height is made up by the superposed cofferdams. Each caisson is 63 ft. 6 ins. long, 29 ft. 6 ins. wide and 18 ft. high, with a working chamber 7 ft. 4 ins. high. The design is shown in Fig. 1, from which drawing the details are evident. It will be noticed that the working chamber is braced by transverse 8 × 16-in. timbers with short vertical 12 × 12-in. struts and that the roof is braced in each direction by rows of trusses made up of 12 × 12-in. verticals, 3 × 12-in. diagonals and 1½-in. tie-rods. In addition the long side walls are tied together with 2-in. rods provided with turnbuckles. All connections are made with ⅞-in. drift bolts either 22 or 34 ins. long as the location demands. The view in Fig. 2 shows one of the caissons before the sheathing has been placed over the framework and illustrates the method of internal trussing above the roof. Horizontal braces not given on the drawing have been added for additional stiffness. Fig. 3 shows the finished caissons on the shore where they were built.

The caisson for Pier No. 1½ was sunk 57 ft., that for No. 2½, 75 ft., and that for No. 3½, 71 ft., all through sand, clay, gravel and boulders to the solid rock. The cofferdams which were placed on the caisson cribs to make up this necessary depth were built of 12 × 12-in. uprights, cross-braces, and waling pieces, with sheathing varying from 6 ins. just above the crib to 3 ins. at the top of the dam. Work of building the cribs and dams started October, 1908, the first crib was launched April, 1909, and the work on all these foundations was completed October, 1909.

Three compressors furnished the air for the chambers through two 4-in. pipes laid along the lower chord of the old truss to a maximum distance of 1,300 ft.

This work was done for the B. & O. R. R. by John Monks & Sons, 82 Beaver St., New York, under the direction of Mr. Frederick A. Schrader, who, with Mr. Charles H. Deans, now deceased, also superintended the design.

Suggestions on the Use of the Iron and Lime Process of Water Purification.*

C. ARTHUR BROWN.†

Dibdin, in England, seems to have been the first to suggest and secure practical results with the iron and lime process of treating water. His recommendations to the Royal Commissioners were submitted to them in 1884. This suggestion embodied the use of four grains of lime and one grain of proto-sulphate of iron for the treatment of the London sewage at Barking and Crossness. In January, 1887, he read a paper on this process before the Institute of Civil Engineers. In this paper he embodied the results of experimental work with various amounts of sulphate of iron and caustic lime in the purification of sewage waters. The general method of preparing and applying the lime solution was similar to processes now employed. At first an impure water was used to make up the lime solution, but the lime-destroying properties of such a water caused such unnecessary waste of lime that later on a purer water was substituted. The iron solution was made up by dissolving iron sulphate in a tank of water heated by steam coil, a concentrated solution being prepared. The iron and lime solutions thus prepared were added to the sewage water in the proper proportions and the results of clarification were considered extraordinarily good at this time and the cost of production exceptionally low.

During the summer of 1897 the writer experimented with ferric sulphate at Lorain, Ohio, attempting to use the material without resorting to the use of an alkali, and during the same summer attempted the use of ferrous sulphate of iron, using carbonate of soda as an alkali. Neither of these processes proved satisfactory.

In 1898 Wm. Jewell devised the sulphate of iron or iron and lime process, which consisted of burning sulphur in a specially constructed furnace and [illegible]rbing the fumes of sulphurous acid thus produced [illegible] water by means of a washing tower. This sulphuro[illegible] acid solution was then drawn off into tanks filled w[illegible]rap iron, and after being allowed to lie in contact w[illegible] the same for several days the acid liquor was applied [illegible] the water to be purified and caustic lime added to [illegible]lize the acid and bring about coagulation. This [illegible]ess was [subsequently] adopted at Quincy, Ill., and [illegible] Lorain, Ohio, as well as at several other points.

In the latter part of April or the early [illegible] of May, 1902, Wm. B. Bull, who was at that time [illegible] of the Quincy Water Works Co., at Quincy, [illegible] began experimenting along this same line with [illegible]phate of iron and caustic lime, in an attempt to [illegible]ify the Mississippi River water. The result of this [illegible]erimental work was such that Mr. Bull purchased a [illegible]derable supply of sulphate of iron from the Americ[illegible] Steel & Wire Co., of Chicago, and began the work [illegible] purification on a practical basis in May, 1902, puri[illegible]ng all of the water supplied the city of Quincy by this m[illegible]od. The writer visited Quincy in the fall of the same [illegible] and became conversant with the results obtained at [illegible] point. As a result of this information, the process was adopted by Lorain in 1903, and by Elyria, Ohio, a [illegible] months later.

In March, 1904, St. Louis, Mo., began using the process. Since then it has grown in favor with a large number of municipalities and has been adopted by many cities for the purpose of purifying their water-supply. The water-supplies of St. Louis, Cincinnati, Indianapolis and New Orleans form the most notable examples of its use on a large scale. The use of the process at these plants has proven satisfactory to date, and it has been employed with satisfaction by a large number of smaller plants.

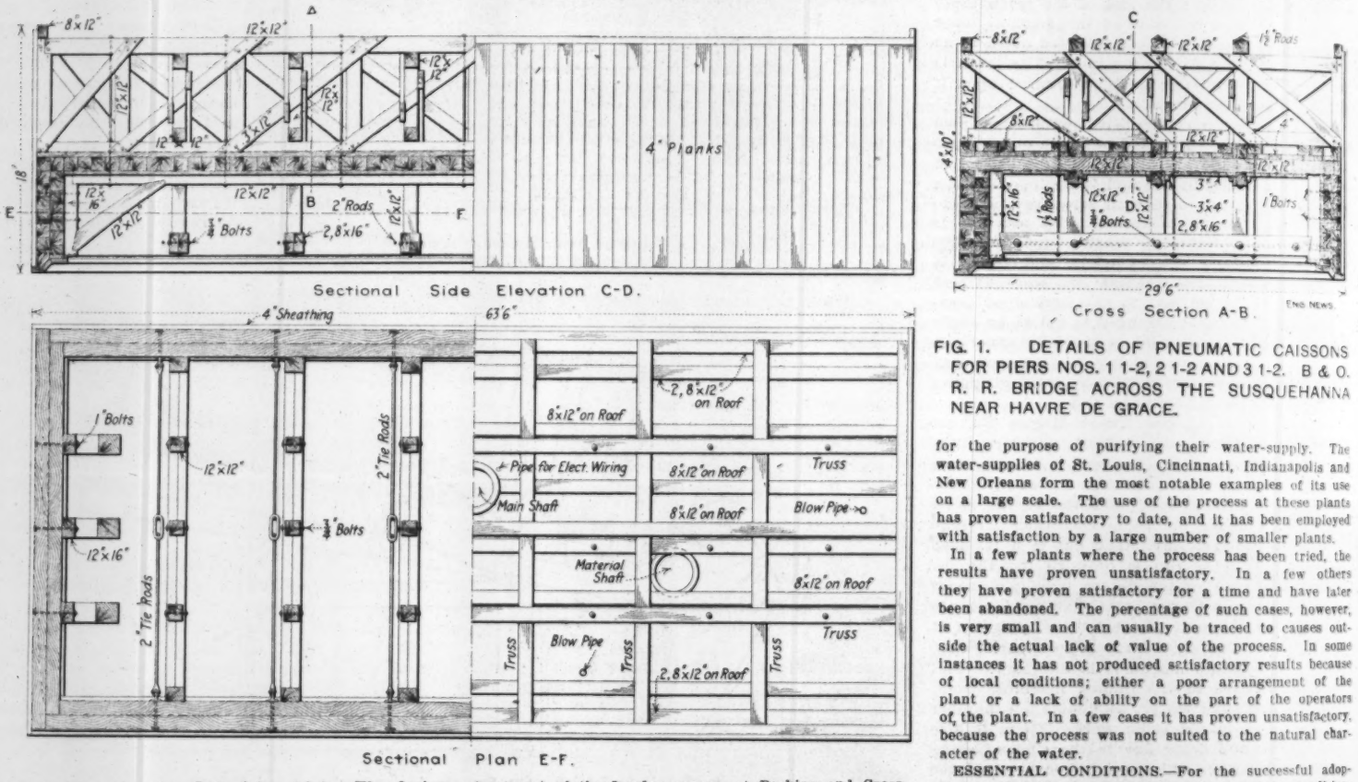


FIG. 1. DETAILS OF PNEUMATIC CAISSONS FOR PIERS NOS. 1 1-2, 2 1-2 AND 3 1-2. B & O. R. R. BRIDGE ACROSS THE SUSQUEHANNA NEAR HAVRE DE GRACE.

In a few plants where the process has been tried, the results have proven unsatisfactory. In a few others they have proven satisfactory for a time and have later been abandoned. The percentage of such cases, however, is very small and can usually be traced to causes outside the actual lack of value of the process. In some instances it has not produced satisfactory results because of local conditions; either a poor arrangement of the plant or a lack of ability on the part of the operators of the plant. In a few cases it has proven unsatisfactory, because the process was not suited to the natural character of the water.

ESSENTIAL CONDITIONS.—For the successful adoption and utilization of this method certain conditions must be fulfilled. It is necessary with our present knowledge to have a certain amount of alkalinity present in the water at the time the iron is added, or the alkalinity required must be given to the water either before or after the application of the iron. It is considered better practice to add the alkalinity after the iron has been applied. The alkalinity which is present in the water-supply such as is ordinarily met with, is of the bicarbonate character; in other words, the alkalinity consists of bicarbonates of lime, magnesia or soda or a mixture of these. In the presence of bicarbonate alkalinity, and particularly if a small amount of free carbonic acid be present, the addition of sulphate of iron to such a water will result in an increase in the apparent turbidity, and the physical appearance of the water will be more unsightly than it was before the iron was added. If this water stands at rest for a sufficient period of time, the sulphate of iron will react with the alkaline carbonates present and considerable carbonic acid will be liberated and gradually escape from the water and thus allow of the complete removal of the iron from solution; but the time period required for this process is too long to enable it to be used in practical water purification methods.

The alkalinity must be sufficient to admit of a complete removal of the iron from solution. The alkalinity required to bring about this result will vary considerably on different types of water. A higher alkalinity will be

*A paper read before the Central States Water Works Association, Columbus, Ohio, September, 1909.

†Sanitary Engineer, American Steel & Wire Co., Lorain, Ohio.

necessary in some waters than in others, and only experience or the judgment of an expert can determine in advance what measure of alkalinity will be required to bring about the result.

COAGULATION.—After the iron has been introduced, the addition of a small quantity of caustic lime will cause the formation of the iron coagulation, and if the process is properly carried out, the coagulation so formed will be excellent in character and have a tendency to precipitate or fall out of suspension more rapidly and completely than does the coagulation resulting from the use of alum under similar conditions. The quantity of lime to be added will depend on the character of the raw water. It must be sufficient to bring about the desired character of coagulation if the best results are to be secured.

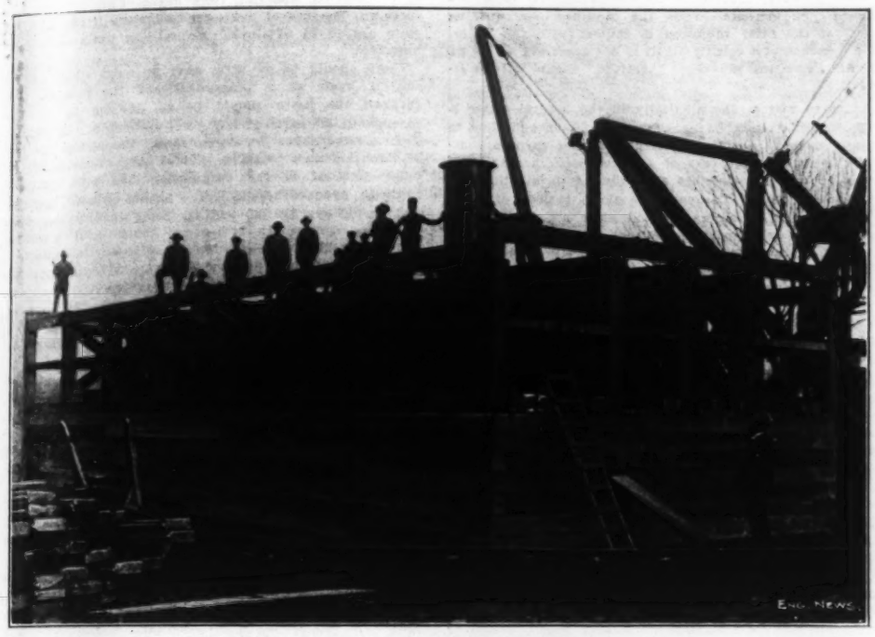


FIG. 2. CAISSON DURING CONSTRUCTION.

The character of the coagulation is indicative of the proper or improper carrying out of the process. The coagulation should first appear in microscopic form, merely as an increase in turbidity. This should progress regularly, the water being kept in somewhat rapid motion during this period of time until, at the expiration of three minutes, the coagulation should be well formed and of fair size of flock. There should be perfect sharpness of definition between the flock and the clear water between the flock. The appearance of the water between the flock should be brilliantly clear when examined by refracted light. When left to stand alone for a few moments, the coagulation so produced should manifest a tendency to settle out of suspension promptly and almost completely, and when filtered through one thickness of filter paper of close texture it should filter brilliantly clear. A circular motion should be given to the test sample during the formation of the coagulation. If the coagulation does not form perfectly in three minutes, its character will certainly be found faulty.

If it forms in much less than three minutes, too much of the chemicals have been employed for economical operation. The quantity of iron required to produce a coagulation of this type, on any given water-supply, can only be known as a result of experiment or experience. The same remarks apply to the amount of iron required as to the amount of lime required and will depend, to a certain extent, upon the end desired. If the water be comparatively high in alkalinity and a comparatively free use of lime be resorted to, then the amount of iron required will be less than if a smaller quantity of lime had been employed. The proper type of coagulation can be thus produced by a free use of either chemical. The amount of lime applied, however, should never be more than enough to produce the desired character of coagulation unless special precautions are taken to prevent trouble arising from too free use of caustic lime. The margin between the amounts of lime which *must* be used, and which *can* be used to bring about this effect is sufficient to enable the result desired to be obtained without danger to the operative success of the process. The same holds true of the use of iron sulphate.

After the proper amount of lime has been employed, it is feasible to vary the amount of iron within comparatively large limits; thus on a water possessing the proper quantity of alkalinity and treated with a sufficient quantity of lime, no more and no less, it is possible to obtain the results desired by using one, two, three or even four grains per gallon of sulphate of iron without materially affecting the results, except as regards cost of chemicals.

There is really no definite relationship between the quantity of iron and the quantity of lime on any given water-supply, owing to the fact that the chemical and physical character of a water-supply will vary within rather wide limits at different times of the year and any chemical treatment required to properly handle such a supply must vary proportionately within the same limits. Where the alkalinity is sufficiently high, it is feasible to determine by a very simple test, as to whether enough lime has or has not been added. If enough lime has been added, the water, after being treated with both iron and lime, will react alkaline to phenolphthalein at the expiration of a three-minute interval after the chemicals have been added and coagulation properly formed.

If a sample of this water be subjected to titration at this time, the normal or mono-carbonate alkalinity of the same will be found to be from 2 to 10 parts per 1,000,000. The decrease in the total alkalinity of the filtered water, as compared with the raw water, should not be more than 10 parts per 1,000,000; at least for any appreciable period of time.

ALKALINITY TESTS.—The test for alkalinity is made as follows: 50 c. c. of the water are taken by pipette and placed in a porcelain evaporating dish or beaker, the beaker if used being placed on white porcelain, marble or paper. Two or three drops of phenolphthalein test solution are added to the water in the dish or beaker. If there be any normal carbonates present the water will turn purplish red, while if only bicarbonate alkalinity be present, the water will remain colorless. A burette is filled with N/50 sulphuric acid and adjusted to the zero point. The N/50 acid is then added from the burette, drop by drop to the water until the last drop just discharges the color in the water. The water must be constantly stirred and some few seconds must elapse after each drop is added just preceding the complete removal of the color. The color is not instantly discharged by the acid, or if so, too much acid has been

FIG. 3. CAISSONS PREPARATORY TO LAUNCHING.

employed. The color should gradually fade under the addition of the acid, growing fainter and fainter until the end reaction is obtained, when the color definitely vanishes upon the addition of the last drop of the acid and the water should remain colorless. When this end point has been obtained, the burette is then read and the number of cubic centimeters and tenths thereof noted. The result so obtained, multiplied by 20, will give the phenolphthalein alkalinity in parts per million.

The test for total alkalinity is made as follows: 50 c.c. of the water are taken by a pipette and placed in a porcelain evaporating dish or a beaker, setting on white enamel, marble or paper. If it is advisable to take another sample of the same water and place in a comparison dish or beaker, standing the one alongside of the other. To these are then added one or two drops of methyl-orange test solution; not more than two drops of the test solution being employed. This test solution consists of a saturated solution in water of Gruebler's methyl-orange. Much trouble has been experienced in preparing this solution, due to the fact that much of the methyl-orange sold for this purpose is not suited for use as an indicator. The writer has never had any trouble with Gruebler's methyl-orange and therefore advises its use. The addition of one or two drops of the test solution to 50 c.c. of the water results in an orange-yellow color being produced. Methyl-orange is yellow in the presence of alkalies either caustic, normal or bi-carbonate, and purplish red in the presence of mineral acids other than carbonic. An N/50 solution of sulphuric acid is used for the titration. This can be purchased at any chemical supply house such as E. H. Sargent, of Chicago; Chemical Engineering Co., Chicago, Ill.; Henry Heil Chemical Co., of St. Louis, or the Scientific Materials Co., of Pittsburg. The procedure is to fill a burette with the N/50 sulphuric acid solution and bring the level of the acid to the zero point of the burette. The acid is added, drop by drop, to the sample which is being titrated, until a *slight darkening* of the indicator shows in the liquid. The first indication of end reaction is the apparent *darkening* of the solution. The burette is then read and the amount of acid noted in cubic centimeters and tenths. After this, the acid is added drop by drop with constant stirring of the sample. After two or three additional drops are added, if it brings about a decided change in the color, the change being from orange yellow to purplish red, the end point is properly obtained, but if this change of color does not occur with the addition of two or three drops of the acid, the operator was mistaken in his judgment regarding the darkening of color which occurred. The two samples treated with methyl-orange standing side by side under the same light conditions, enable the operator to judge more quickly and accurately when the end point is obtained, as the one to which no acid is added remains of the same color while the one to which the acid is added changes color when the proper end point has been reached. The reading of the burette in cubic centimeters and tenths must be multiplied by twenty in order to obtain parts per million, and the result so found is the alkalinity present in the water. If the phenolphthalein alkalinity is exactly one-half the total alkalinity, then the total alkalinity and the normal carbonate alkalinity are one and the same. In other words; if the phenolphthalein alkalinity multiplied by two just equals the total alkalinity, then all of the alkalinity present is normal or mono-carbonate alkalinity. If, however, the phenolphthalein alkalinity multiplied by two is less than the total alkalinity thus obtained, the phenolphthalein alkalinity multiplied by two will give the normal or mono-carbonate alkalinity, and the normal or mono-carbonate alkalinity subtracted from the total alkalinity will give the bicarbonate alkalinity. In case the phenolphthalein alkalinity multiplied by two is more than the total alkalinity, then no bicarbonate alkalinity is present. In this case the alkalinity is composed of caustic and normal carbonate alkalinity. In such a case the phenolphthalein alkalinity is subtracted from the total alkalinity and the remainder multiplied by two gives the normal carbonate alkalinity. The normal carbonate alkalinity subtracted from the total alkalinity gives the caustic alkalinity. In the first place the sum of the normal carbonate alkalinity and the bicarbonate alkalinity must agree with or equal the total alkalinity. In the second place, the sum of the normal carbonate alkalinity and the caustic alkalinity must equal the total alkalinity.

DESIRABLE ALKALINITY LIMITS.—A common belief obtains in some quarters that if a water reacts alkaline to phenolphthalein test solutions such a water contains caustic alkalinity. This, as is seen from the above, may or may not be true and can only be determined by the test given above.

In some cities a water containing caustic alkalinity has been supplied to the people as drinking water for considerable periods of time without injury to the health of the community. St. Louis forms the most notable example of such usage. For the larger part of two years the drinking water supplied the citizens usually contained from 2 to 40 parts per 1,000,000 of caustic alkalinity. During this period of time an improvement in the public health as regards water-borne diseases was noticeable, while no noticeable harm to the users of the water resulted from this practice. While it is possible that no harm would result to any community from drinking water containing this quantity of hydrate of lime, it is nevertheless very bad practice to resort to, and the presence of a caustic alkali, even of lime, should not be permitted. If a water of this kind were to be passed through mechanical filters, trouble would result by the formation of scale or incrustation on the sand-bed and working parts of the filter subjected to contact with the water. The presence of a caustic alkali is not necessary to secure results, and its presence, therefore, should not be allowed.

In cases where the alkalinity in the natural water is low, it will usually be necessary to add enough lime to bring about a considerably larger normal carbonate alkalinity than in the case of a water high in alkalinity. Some of our water-supplies are quite low in alkalinity at certain seasons of the year for short periods of time. Thus, some of these waters will show an alkalinity as low as eight or ten parts per million at such times. With a water of this type it is necessary to use considerable lime to bring about normal carbonate alkalinity therein sufficient to result in the precipitation and removal of all of the iron sulphate added as coagulant. The quantity of lime required will naturally depend on the quantity of iron employed. In most cases where the alkalinity drops to a low point, the turbidity increases in inverse ratio to the fall of alkalinity, so that at times when the smallest alkalinity is found in the water it is necessary to use the largest amount of iron in order to secure satisfactory coagulation, and the amount of iron required in connection with the low alkalinity of the natural water involves a larger use of lime at such times. Therefore, in cases of this nature it is necessary to have a larger normal carbonate alkalinity in the filtered water than if the alkalinity of the raw water was up to the normal. In a case of this kind it is advisable to limit the total alkalinity of the filtered water to a point below 50 parts per 1,000,000, and it is advisable to reduce the total alkalinity to as low a point or as much below 50 parts per 1,000,000 as is practicable. The normal carbonate alkalinity at such times may be 10, 20, 30 or even 40 parts per 1,000,000 with a bicarbonate alkalinity ranging from 40, 30, 20 or 10 parts per 1,000,000. The bicarbonate alkalinity should not be totally eliminated, as this is usually unnecessary. The essential feature of the process at such times is that the total alkalinity shall not rise above 50 parts per 1,000,000 in the filtered water.

A water carrying no more than 50 parts per 1,000,000 of alkalinity will have but little, if any, tendency to scale or incrust the metallic parts of the filter or the sand-bed thereof, owing to the fact that very nearly this quantity of lime is soluble in water void of carbonic acid, and therefore, there is little, if any, tendency for the lime compounds to separate out and form an incrustation. In some of the softening plants where the water is reduced to an alkalinity as low as this, plants which have been in operation for years have shown no tendency to scale or incrust, and at others the amount of scale so deposited amounts to a mere film which manifests no tendency to increase in thickness. If, however, the alkalinity of the filtered water at such times amounts to 60 or 70 parts per 1,000,000, or if the alkalinity be reduced from a higher point, say 100 parts per 1,000,000 to a 60 or 70 parts per 1,000,000 alkalinity by the use of lime on a softening basis, then there is an actual tendency for incrustation to form on the sand-bed and working parts of the filter subjected to contact with the water treated. These things being true, it is a comparatively easy and simple matter to prevent scale or incrustation.

A mechanical filter plant is not ordinarily built as a softening plant and should not be used as such. If the city desires a softening plant, it should build it and take proper precautions to avoid difficulty from using it. In some places it seems almost imperatively necessary to effect a softening action and in these cases there is usually a sufficient financial inducement to do so to pay for the construction of a softening plant. In a few instances where mechanical filtration plants have been used for softening purposes it has proven commercially possible to use the plant as a softener and stand the expense inherent thereto and still make money, but this consists in an abuse of the mechanical system of filtration and not in a proper use of the same, and should not, therefore, be charged up against either the plant or the process in use.

TREATMENT AFTER ADDING CHEMICALS.—After the chemical treatment has been given, it is essential that the water be kept in rather rapid motion for a period of at least three minutes and preferably for a five-minute interval of time. The speed of the water at this point should not be less than 1 nor more than 5 ft. per sec. This can usually be accomplished best by baffling a small part of the settling basin and causing the water to flow around these baffles at the speed required. It is necessary to give the water this comparatively high rate of flow in order to secure a proper formation of the coagulation.

SEDIMENTATION.—After the coagulation has been formed, the flow through the sedimentation basins should be reduced to the lowest rate of flow practicable. The settling basins should be open to inspection so that the operator may watch the formation of the coagulation and the sedimentation effects through the settling basins. Settling basins should not be covered in such a way as to prevent the operator from seeing what is occurring therein. The use of baffles is obligatory if the best results are to be obtained. No settling basin should go unbaffled.

There should be as little dead or quiet water in the settling basin as is practicable and the rate of flow through the basin should be as uniform as possible throughout all parts or any cross-sections of the settling basin located above the sludge zone. The slower the rate of flow the more complete will be the sedimentation results obtained if the coagulation has been properly formed. Around the end baffles should be used, the over and under systems of baffling being inadvisable, inasmuch as it involves either too much dead water or actually results in prevention of sedimentation effect.

The sedimentation process of the mechanical filter system is probably the one which has received the least attention from engineers and it is, in reality, one of, if not the most important feature of the system. It is absolutely essential that progress be made along this line, and engineers must devote a greater amount of attention and study to this feature if the best results are to be obtained. In some of the plants now in operation, the lack of baffles in the basins is painfully apparent, and the results obtained by sedimentation, from one cause or another, are much below what might be obtained if a proper consideration of this problem had been given. We regard this as one of the weak points of the mechanical system, and believe that a proper study of the problems involved will result in a great improvement in the design and construction of the settling basin of the mechanical filter plant.

The depth of sludge in the settling basin should never be permitted to rise above a certain height. It is impossible to state what depth of sludge should be permitted in any basin before cleaning, without having a comprehensive knowledge of the local conditions. It is feasible to permit a greater depth of sludge in some basins than in others, but there is a point for every one, above which the sludge should not be permitted to rise. When this point has been reached, the basin should be cleaned, as otherwise inferior results must be obtained.

SLUDGE-DEPTH GAGE.—The writer has used a device for some little time which enables one to ascertain the depth of sludge at any point with almost absolute accuracy and at a minimum of time and effort. This consists of a rod made of wood approximately 2 ins. in width, 1 in. in thickness and as long as the settling basin is deep. Bottles are fastened to this rod, 6 ins. c. to c. These bottles should be of about 2-oz. capacity and the mouth should be nearly as large as the body of the bottle. The rod, with these bottles fixed carefully in place, is slowly lowered into the basin to be tested. As soon as a bottle is immersed it fills with water, the mouth of the bottle looking upward. The rod, after being carefully lowered to the bottom, is raised very slowly from its position until the bottles begin to appear one by one. The first bottles rising above the surface will contain the coagulated water and be comparatively free from sludge, but when the rod has been raised high enough, it will be observed that all bottles located below a certain point are filled with sludge. Usually the first bottle containing sludge will have only a small quantity of sludge, while the ones below it will gradually increase in the quantity which they contain until the bottles are filled solidly. The rod, if stood on end and looked at from the side, will give a fair illustration of the vertical cross-section of the settling basin at that point as regards the character of water and sludge in the basin at that point. A little experience with a sludge rod of this type enables the operator to determine when the basin has enough depth of sludge therein to make cleaning advisable.

The water which has passed through the settling basins should be conducted into and onto the filter beds with as little disturbance as possible. The rate of flow between the basins and the filters should not be higher than is absolutely necessary. Any sharp increase in the rate of flow or any violent disturbance of the water at this time will result in breaking up the coagulation to a certain extent and this will render the process of filtration somewhat more difficult than if the water be conducted quietly from the basin to the filters.

Sharp bends in pipes or conduits should be avoided. The water should not be permitted to make sharp turns at right angles if it is possible to avoid doing so.

The size of the sand should be adapted to the work which it is to perform. Coarse sands are to be avoided save in plants where clarification is the only end desired.

Under the proper conditions of operation, the settling basin should remove from 60% to 95% of the suspended matter and bacteria contained in the raw water. It is remarkable how many bacteria can be removed by sedimentation if the basins be properly constructed and a

proper coagulation maintained. It is no unusual matter to find sedimentation results running as high as 90% or even 95% removal.

FILTER SAND.—In plants where such results are obtained, it is obvious that the filter will have but little to do, and, therefore, the size of the sand should not be too coarse. The effective size of the sand in most of the successful plants is approximately .37. Finer sand is used in a few plants, and coarser sand will be found in many plants which are not producing equally as good results. In one plant which the writer visited recently, the effective size of the sand was .57. Needless to say, the results from this plant were not as satisfactory as was desired.

Preparing and Adding Chemicals.

The application of the chemicals to the water is another important part in the process. The chemicals must be applied with a fair degree of accuracy and this point has been overlooked or neglected in many plants and has resulted, therefore, in more or less failure in obtaining satisfactory efficiencies. It is essential that each portion of the water receive approximately equivalent treatment with every other portion of the water. Unless the plant can be provided with an apparatus which will insure this, there is little chance of obtaining satisfactory results. This is usually easily obtained in the application of the iron sulphate. The difficulty usually comes in applying the lime to the water. The iron sulphate can be made up in definite strengths, and ordinarily a fairly accurate application of the solution can be secured. The rate of diffusion of the iron sulphate is comparatively high, and its tendency to mix uniformly with the quantity of water to which it is applied is large and, therefore, if the iron be applied to the water previous to its passing the low service pumps usually found in our mechanical systems, the sulphate of iron will be thoroughly mixed with the water before it reaches the settling basins.

LIME.—With the lime, however, a larger difficulty obtains. Lime does not form a solution of sufficient strength to enable it to be used in the same way as sulphate of iron. The average lime water will not contain more than 60 to 65 grains of calcium oxide per gallon, and in many cases it is much weaker than this. Milk of lime can be made of any strength desired, but, in the case of milk of lime, the tendency is for the suspended lime to drop to the bottom of the tank in which it is stored, leaving only lime water at the surface. Unless a mechanical system of agitation is employed, the result will be that unequal strength of milk of lime will obtain at the top, middle and bottom of the lime storage tank. If this be used in this way and the solution taken from the bottom of the tank, the strongest lime will be obtained from the bottom of the tank and the weakest from the top.

The best system of maintaining an accurate strength of milk of lime consists in a set of small propeller blades not more than 6 or 8 ins. long, driven at a somewhat high rate of speed, say from 500 to 700 r. p. m. This impeller blade must be placed near the bottom of the tank and must be enclosed in a cylinder having a cone-shaped bottom, the bottom of the cone having a clearance of about 2 ins. from the bottom of the chemical tank. The cylinder should be about 12 ins. in length and the diameter of the cylinder should be just sufficient to allow the impeller blades to clear in it. The thrust of the impeller blades should be upward, thus having a tendency to lift the shaft from its bearing at the bottom. When the shaft is driven at the speed required, the milk of lime is forced to flow into and down through the cylinder, out through the cone, across the bottom of the tank, up the sides of the same and down the center. A whirlpool effect is noticeable in the level at the top near or around the revolving shaft. The flow of lime down through the cylinder and across the bottom of the tank and up the sides thereof maintains a perfect suspension of the milk of lime, and, therefore, it makes no difference whether the tank is full, half full or nearly empty, the strength of the milk of lime in the tank will be approximately the same in all parts, and hence it can be applied to the water with a fair degree of accuracy of application.

CHEMICAL FEEDING DEVICES.—Many devices are in use for applying the chemicals. In some instances pumps are used to pump the chemical solutions into the water to be treated. In others the chemical storage tanks are set at sufficient elevation to enable the chemicals to be applied by gravity from the chemical tank. In others, the chemical solution is conducted to a head tank which sets at a sufficient elevation to apply its contents by gravity to the water to be treated. The latter is by long odds the most feasible if we exclude the automatic device designed by Mr. Geo. G. Earl, General Superintendent New Orleans Sewage and Water Board. The head tank is so regulated that a constant level is maintained therein. This can be done in any one of several different ways. The ordinary method of procedure is to pump the solution to the head box and provide a weir overflow from the head box back to the chemical storage tank. In this way the pump discharges more chemical solution to the head tank than is being applied to the water, and the surplus so pumped overflows the weir of the head box, returns to the chemical storage tank and assists in maintaining a suspension and even strength of the chemical solution, or suspension in the chemical storage tank. This system has been carried out very effectively in the construction of the Lorain filter plant, built by the Pittsburg Filter Mfg. Co.

The device designed by Mr. Earl is superior to this, inasmuch as it involves all that has been said in regard to maintaining the strength of the solution or suspension, and in addition, it provides an apparatus whereby the amount of chemicals varies automatically in direct ratio with the quantity of water undergoing treatment. The fault of the device first described is that it applies a uniform quantity and strength of chemical solution or suspension at all times when set on a given orifice. If, therefore, the quantity of water passing into the settling basins is larger or smaller at one time than another, the water will receive smaller or larger quantities of chemicals than at others. With Mr. Earl's device, however, the quantity of chemicals applied is independent of the rate of flow into the settling basin, and varies in direct ratio with the quantity of water being treated. The device is automatic in its operation, but it is difficult to describe clearly in a paper of this kind. It is not saying too much, however, to state that the device as installed by Mr. Earl for the New Orleans purification plant is a great advance over anything that has yet been accomplished along this line.

The advantages of having a well-designed chemical feed device which is accurate and automatic in the application of chemicals can hardly be overstated. In the mechanical plant much depends upon the accurate application of the chemicals, and any device which insures this should be installed regardless of the cost.

With the foregoing precautions, the results from the iron and lime process at plants where the raw water is suited for its employment, will be found satisfactory and much more economical than any of the older processes, the usual cost being about one-half that of the older processes. With this process it is possible to meet conditions which cannot be met successfully by a one-solution coagulant. The process is more flexible, and gives the operator a better chance to vary the chemical treatment as occasion may arise, and in this way to vary the results obtained so as to meet almost any conditions which may arise.

SUBSTITUTES FOR LIME.—Some recent discoveries have been made in regard to the use of the iron and lime process. The writer has found that the use of live steam in small quantities will effect the same results as though lime were employed. This process has been given a trial at Elyria, Ohio, undergoing a thorough test for thirty days. The results obtained were entirely satisfactory, the chemical cost falling as low as 57 cts. for a considerable period of time during the test. The amount of steam required at this plant was approximately 1,000 lbs. per 1,000,000 gals. filtered. The water was first treated with sulphate of iron as in the ordinary iron and lime process, and live steam injected into the conduit carrying the iron-treated water from the pumps to the settling basins. A report on this process will be forthcoming in a short time. This process has not been given a sufficiently thorough test at other points to prove its general usefulness.

The writer also discovered the fact that the same effects could be obtained by the use of electricity. If an electric current be caused to pass through the iron-treated water, a coagulation results and the removal of the iron is as complete as with either the lime, air or steam propositions. This process has not been given a practical trial in any plant up to the present time and its cost is only known from an experimental standpoint, in which it is assumed that the cost of electricity will be about 30 cts. per million gallons of water treated.

The writer also discovered that the same results could be secured by giving the water a direct mechanical agitation after the iron treatment had been given. This process has not been given a practical try-out and the cost of the same is known only experimentally, it being assumed that this cost will be approximately that of treatment with electricity. There are some indications that the cost may exceed the cost with electricity under certain conditions, but enough work has not been done with either of these three processes to prove their actual value.

The steam process has been tried out at one or two other points and has produced varying results, in some instances being bad; in others, good. An inquiry is being made into the causes of such actions with a view to eliminating these difficulties if possible and practicable. The alkalinity of the treated water evidently plays a very important part in the good and bad results thus obtained, and the same thing will probably hold true in regard to the electrical and mechanical agitation propositions. In these three last-mentioned processes it will also be necessary for the water to contain enough dissolved oxygen in its natural condition to permit of the oxidation of the iron salts added for coagulating value. As most of our natural waters contain a sufficiency of dissolved oxygen for this purpose, it is not thought that any difficulty will be experienced in this direction save in rare instances. The removal of the organic matter by the steam process is rather remarkable and it is also apparently true that the amount of steam applied has an actual germicidal action, the results at Elyria seeming to indicate that 50% of the bacteria are killed by the application of the steam and iron before sedimentation occurs.

It is also apparently true that the steam exercises no selective germicidal action. If so, the ordinary water bacteria are more susceptible to its action than the pathogenic. As far as could be ascertained, there was no tendency of the steam to exert a germicidal action as far as the colon bacillus was concerned in the test spoken of. The coagulation resulting from the use of these new processes forms much more slowly than it does when caustic lime is employed. With the three last-described processes the application of the steam, electricity or mechanical agitation can be made automatic and no harm will result from too much steam, electricity or mechanical agitation being applied. The results are obtained with apparently very small quantities of steam and electricity. A great deal of work is being done on these different propositions, and reports will be made public as soon as the data at hand is sufficient to warrant an accurate judgment of the value of the same.

A Novel Design of Self-Cooled Transformer.

There has been a demand for self-cooling transformers in sizes above the limit for which standard cases with corrugated sides can be designed. The heat radiating capacity of these cases has been sufficient in sizes up to about 750 KVA. Above this point such cases have not been practicable and a new type has been necessary. The demand for larger self-cooled transformers comes from installations when cooling water is not available or is expensive,

A 1,000-KVA. Self-Cooled Transformer, with Outside Radiation Tubes.

where severe weather conditions cause trouble with the circulating system, or where it is necessary to cut attendance to a minimum.

The new case, built by the Westinghouse Electric and Manufacturing Co., of Pittsburg, for the Southern Power Co., of Charlotte, N. C., consists of a plain boiler-iron case, as shown in the accompanying figure. To the outside of the case are welded a number of radiation tubes. These tubes are in a vertical position and are given a 90° bend at the top and bottom where they enter the case. The mechanical construction is made strong so that there is little chance of a leak. Because of the separation of tubes the air circulates very freely among them and

the efficiency of the radiating surface is considerably higher than for the ordinary corrugated case.

The transformers built for the Southern Power Co. were of a capacity of 1,000 KVA., at 100,000 volts.

A Sand and Tar Base for Plank Flooring on Reinforced-Concrete Floor-Slabs.

The accompanying half-tone is a view of the second story of a new reinforced-concrete factory built for the Blake & Johnson Co. at Waterville, Conn., and illustrates a new method, or rather a new application of an old method, of flooring construction. The engineers for the building disliked to lay the flooring directly on sleepers embedded in the concrete slab, as is usual in such structures, for fear that dry rot would soon destroy the sleepers and the flooring immediately next to the concrete, so they adapted to this upper story the old practice of filling between the ground of a first story and its flooring with a layer of sand mixed with coal tar.

On this job, a mixture of 50 gals. of coal-tar (Barrett's No. 5) to each cu. yd. of sand was spread 1¼ ins. thick on the floor slab and leveled while still warm and soft with a straight edge. On this layer there was then placed first a layer of 2-in. plank, then ⅞-in. rough pine board and finally a wearing surface of 1¼-in. square-edge maple. These different layers of planking were placed in different directions.

The weight of the planking compacted the sand-tar layer to about 1 in. in thickness. The floor now is solid but resilient and comparatively noiseless.

SAND AND TAR BASE FOR FLOORING ON SECOND FLOOR OF THE BLAKE & JOHNSON CO. FACTORY; WATERVILLE, CONN.

Weak Points in Old Railway Bridges.

The notes abstracted below contain helpful suggestions for the examination of old bridges. They are taken from a paper prepared for the International Railway Congress by Mr. M. L. Byers, M. Am. Soc. C. E., of the Missouri Pacific Ry., and published in the September, 1909, "Bulletin" of that association. The paper is to be presented at the Congress which is to be held in Switzerland next year. The paper concerns itself with railway bridges, being a discussion of how track and bridges can be strengthened to carry high-speed trains. But much of the remarks on bridges is equally applicable to highway bridges.

The problem of *strengthening* bridges does not arise frequently. But very frequently bridges need to be examined to determine whether they are still able to withstand safely the growing severity of traffic, and the quoted remarks refer to such examinations. A previous paper on the same subject, by Mr. W. J. Watson, M. Am. Soc. C. E., printed in our issue of Aug. 23, 1906 (p. 200), under the title "Concerning the Investigation of Overloaded Bridges," gave expression to a number of general principles which should be observed in examinations of this kind.* The present paper deals more with details, and thus supplements Mr. Watson's study.

Certain classes of defects are of frequent occurrence in the older structures. All bridges in which the full load is carried directly by a single member, such as a floorbeam hanger, or hip suspender, should be given particular attention. The wearing away of counters and floorbeam hangers, the rotation of pins, the working of joints, etc., are signs of weakness, and bridges in which they occur require careful watching. These weak points usually make themselves known by streaks of rust, cracking of paint, loosening of rivets, excessive deflection and vibration under trains.

The type of structure has much to do with the extent to which overloading can be permitted. The deck plate-girder is practically the safest type; if failure takes place, it occurs gradually and furnishes ample warning to a careful inspector. The through plate-girder appears to be next in order of safety, the floorbeam and stringer connections, the increased number of parts, and the danger of injury from derailed cars being taken into consideration.

The riveted deck truss approximates the deck plate-girder in safety, but has many more connections and details. Next comes the pin-connected deck truss, in which the chance for motion and wear on account of comparatively loose pin connections is added to other dangers. The riveted through truss is liable to greater injury from derailed cars than is the through plate-girder. The pin-connected through truss occupies the bottom of the list on account of the greater danger from blows of derailed cars, and also because of the possible increase in wear at the joints.

Defects seldom, if ever, appear in the main members but rather in the details.

FLOOR SYSTEM.—The floor system is one of the first parts of a bridge to show signs of distress on account of increase in load and speed. Defects occur earliest in the connection angles. The rivets connecting these angles to the web become loose and either shear off or become seriously worn. Failure of these angles frequently occurs when the computed stresses do not indicate danger, the secondary stresses that cannot be computed usually being responsible.

FLOOR HANGERS.—Three types of floorbeam hangers most frequently met with are the double U hanger, the single U hanger and the plate hanger. The two former are adjustable, and are usually found in poor adjustment and frequently unduly stressed on this account. The bearings at the lower ends of the double U hangers are seldom so arranged that the stress is equally distributed among the four rods, and it is practically impossible to obtain this result.

The use of floor hangers practically prevents the adoption of any efficient connection between the floor and the trusses for the transmission of horizontal stresses, much lateral motion and swaying under trains resulting therefrom.

HIP SUSPENDERS.—The uneven distribution of load between floorbeam hangers affects the remainder of the truss, more particularly the hip verticals. Especially is this true when the vertical consists of a number of eyebars, as is frequently the case; it results in one bar receiving the greater part of the load, which overstresses it and produces a permanent set.

SHELF ANGLES.—These have been used under various conditions since the first metal bridges were built, and in many bridges in use at the present time they play an important part in the support of the floor. In many cases, they are subjected to stresses which cannot be computed; also, due to their being located in more or less inaccessible places, they are often subjected to serious corrosion.

GIRDER WEBS.—In many old structures, the placing of stiffeners has been unsatisfactorily carried out, insufficient stiffness being often found at points of local concentrated loading, such as over the bearings at the ends of the girder.

WEB SPLICES.—Many girders have been designed on the assumption that the webs would carry all of the shear, and the flanges would resist the entire bending moment. In such cases, the splice rivets near the flanges will, in many cases, be over-strained by the bending stresses thrown on them by the deflection of the girder and will loosen the web splice, the latter losing much of its strength, which must then be supplied by the flanges. The splices near the center of a girder designed in this manner are usually particularly weak.

GIRDER FLANGES.—Weakness of this detail is generally due to insufficient rivets, short plates, or too little section.

The weakness due to insufficient flange rivets is more serious in deck than in through bridges, and, as a rule, the weakest point will be found at a section where there is a noticeable change in the rivet pitch.

Short flanges may be due to an error in computing the proper length of the plate when the girder was designed, or to difference in shape between the moment curve for the loads used in the design of the bridge and that due to the loads in actual service.

The least net section of a tension flange must always be carefully located. It sometimes occurs that there are more rivet holes punched in a plate or angle at some one section than good practice would warrant. This may be due to unusual rivet spacing in the vicinity of floorbeams or lateral connections, or to oversight or carelessness in detailing the girder.

COUNTERS.—The increase of stress in a counter is greater than the increase in live load and, consequently, the counter is usually the most overloaded member of the bridge. In addition, heavier loading frequently requires the placing of counters in additional panels. A sagging counter in an old bridge is always a sign that this member is over-strained.

HIP JOINTS.—As a rule, the hip joint is the most severely stressed of any in a truss and, in short-span pin-connected trusses, defects will frequently be found. The hip suspender frequently carries uneven loading to this point and also transmits to it much shock and vibration, which has a bad effect upon the joint as a whole, resulting in much wear and deterioration.

ECCENTRICITY.—Many unsymmetrical members are found in which the center line of stress does not coincide with the neutral axis, thereby inducing secondary bending on account of the eccentricity. The effect is further complicated by the bending of the member due to its own weight, this resulting in a very uneven distribution of stress over the cross-section of the member.

LATTICING.—The latticing between the various portions of a compression member may be too light to permit the member to be stressed to its full value.

BRACING.—Insufficient transverse and lateral bracing is a serious defect, permitting of sufficient motion to cause the bridge to deteriorate rapidly.

QUALITY OF MATERIAL.—Perhaps the most uncertain element in considering the strengthening of existing metal bridges, is the quality of material contained therein; some of it is wrought iron and some of it is steel, either may be very good or very bad, and there is no satisfactory way of ascertaining, except by removing parts for testing. Crystallization is often found in members due, in some cases, to defects in manufacture, and in other cases, to the effect of shock and overloading. The lack of homogeneity is sometimes of extreme seriousness.

*See also a discussion of the paper, Eng. News, Sept. 13, 1906, p. 282.

ENGINEERING NEWS

A Journal of Civil, Mechanical, Mining and Electrical Engineering

Published every Thursday by

THE ENGINEERING NEWS PUBLISHING CO.

220 BROADWAY, NEW YORK

BRANCH OFFICES

CHICAGO: 1636 Monadnock Block
WASHINGTON, D. C.: Home Life Building
SAN FRANCISCO: Monadnock Building
RUDOLPH MOSSE, BERLIN AND HAMBURG, GERMANY
Z. P. MARUYA & Co., Ltd., TOKYO, JAPAN

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Some of the amateur transportation experts who are gridironing the country with a network of projected inland waterways held a convention at Fort Wayne, Ind., Nov. 10 and 11 to boom the project for a ship canal between Lake Michigan and Lake Erie. They placed several congressmen and senators on the rack and compelled them to swear allegiance to the project, to the extent at least of favoring an appropriation for a survey.

According to the newspaper reports, the convention was "red-hot with enthusiasm," and one of the congressmen who addressed the convention, declared that "we can all readily see the benefits of this waterway." What the benefits were, however, neither this speaker nor any one else condescended to demonstrate. The general claim is, of course, that a waterway from the head of Lake Michigan to Lake Erie in a fairly direct route would save the long voyage through the length of Lake Michigan, Lake Huron and Lake St. Clair. This "saving" appeals to the amateur, but to the practical steamship navigator it is the climax of absurdity. The distance from Chicago to Lake Erie by the present route is in round numbers 650 miles. In the absence of any surveys, the length of a canal from Toledo to Chicago, by way of Fort Wayne, Ind., can only be guessed at; but 250 miles would probably be the smallest distance that could be attained, and a summit elevation of 175 to 200 feet would have to be overcome, requiring probably 20 to 30 lockages for each passage. Suppose, for the sake of argument, that some benefactor were to furnish the hundred or two hundred million-odd dollars which such a canal would cost to construct, and that the canal were built and ready for use, would there be any advantage to lake vessels in passing through such a channel instead of taking the present route through the open lake? If the reader will make a computation, taking into account the difference in speed in a canal and in deep water, and the delays in a canal for passing through locks, passing other vessels, drawbridges and other obstructions, he will find that the lake vessel sailing from Chicago by way of the Straits of Mackinac would probably reach Lake Erie sooner than the vessel which should try to make the passage through the canal. There would be no gain in safety either, by the canal route, since sailing in contracted channels always involves greater risk than sailing in open water.

We deem it worth while to call attention to this project because it has been given much space in public prints, and because it is a fair example of the dense ignorance with which the movement for inland waterway improvement is engineered. It is a fair sample, moreover, of a large number of waterway schemes which are being promoted with as much enthusiasm and assurance as if they really were measures of large public benefit. Commenting on this scheme, the Pittsburgh "Dispatch" well says:

> It is time for the supporters of genuine waterways to put a stop to saddling the subject with fake waterway projects, born only of a desire to get the expenditure of government money.

According to belated press dispatches sent through with great difficulty on account of the damage done to the cables by the recent storm in the West Indies, the rainfall on the island of Jamaica for the four days from Nov. 6 to 10 was recorded as 48 ins. In the confusion necessarily resulting from the flood and hurricane these figures may not be authentic, but if they are accurate they indicate one of the heaviest prolonged rainstorms ever recorded in this hemisphere.

It is difficult for one accustomed to a temperate climate to realize what a 12-in. daily rainfall for four successive days means. Most persons know that the annual rainfall in the eastern and central parts of the United States is between 30 and 50 ins., but even that does not afford a very tangible basis of comparison; though to imagine compressing the rain of a year into four days gives some idea of the amount of water the earth had to take care of in Jamaica last week.

Records of tropical rainstorms are not easily procurable nor particularly reliable when found, but one or two records of tremendous storms, considered the local maximum at the time of their occurrence, will serve as a gage by which to estimate this Jamaica rain.

In Guatanamo, Cuba, on Oct. 13, 1901, there was a rainfall of 17.46 ins. in 24 hours, during 3¾ hours of which time an average of 2 ins. per hour fell. On July 26-27, 1897, the U. S. Weather Bureau recorded at Jewell, Md., a fall of 14.75 ins. in 18 hours, and on Nov. 4, 1899, the American engineers investigating the Nicaragua Canal project reported a fall of 12.48 ins. in 22 hours at Greytown. On the Isthmus of Panama, the record rainstorm since the American occupation was 10.48 ins. in 24 hours at Gatun, in December, 1906, and the highest monthly record in 33 years is only 30 ins. At the foot of the Himalaya Mountains in India, a locality where the annual precipitation sometimes reaches 700 ins., there has been recorded a fall of 30 ins. in three days and as high as 18 ins. in 24 hours.

All these are scattered records and though not necessarily the highest concentrated precipitations ever observed, they were of sufficient magnitude to warrant their being recorded as maximums by the local authorities. Yet no one of them is as great as the reported record from Kingston. There is small wonder that floods and destruction followed such a storm.

Is there any country on the face of the globe which does not suffer from placing broken-down or otherwise incompetent men on the public payrolls? It was long customary, and the habit has not yet been outgrown, for American municipal reformers to point to municipal government in Great Britain as ideal. This rosy view was largely due to the color of the eye-glasses which appear to have been worn by Mr. Albert Shaw when he made the observations on which he based his "Municipal Government in Great Britain." Those who tempered the ideas conveyed by that book by a reading of the British journals devoted to municipal affairs were impressed by the fact that there was no lack of grounds for adverse criticism of British municipal administration, at least from the viewpoint of the British technical press, save from the British themselves.

Although we have called attention to this matter from time to time, we venture to cite still another confirmatory incident which possesses more than usual interest. According to the London "Surveyor," for Oct. 15, the local authorities of Middlesborough, England, deemed it advisable to appoint an investigation committee to examine into conditions relating to municipal employees. While it is probably true that very few committees of this sort could honestly make so favorable a general report, yet some of its findings are very much like what one might expect to see recorded in the report of a committee which had been going over affairs in Boston, New York, or Philadelphia. To quote from the "Surveyor":

> The committee found that, with one exception, the departments are not overstaffed, and that the rates of wages, whilst comparing favorably with the rates paid for similar service elsewhere, are not unduly high. . . .
> A somewhat weak spot was exposed in the streets department, where it was found 20 men were employed at wages aggregating about £1,000 per annum who were quite unfit to perform the duties allotted to them. This was obviously an unbusinesslike state of affairs, but the explanation, which appears to have been duly tested and accepted by the Investigation Committee, is quite a familiar one—one, in fact, with which surveyors and road superintendents have an intimate and painful acquaintance. Men, it appears, had been taken on at the instance of aldermen and councillors, although the superintendent, acting on his own judgment, would not have employed them. It is unnecessary to point out that this kind of intervention on the part of aldermen and councillors in the interests of decayed dependents or servitors whom they ought to assist or succor themselves involves a double injustice. It is unjust to the official in charge, and it is unjust to the ratepayers. It is, of course, a highly objectionable feature of municipal life, but it is really surprising how many gentlemen of otherwise blameless rectitude are in the constant habit of pressing into the service of the municipality men whom they would decline to take into their own service or recommend to the attention of their business friends or acquaintances.

If this is the worst that the committee could find, it certainly speaks well for the general conduct of municipal affairs in Middlesbrough. It is to be noted that the appointment of incompetents is not ascribed at all to the influence of party politics, but wholly to personal sympathy and a desire to find a place for those who had some personal claims on members of the municipal government. While this is far from the ideal in municipal government, it is much less reprehensible than some of the causes which give rise to placing incompetent men on the payrolls of American cities.

No engineer interested in the business of transportation should fail to inform himself concerning the great changes which are going on in the production and consumption of food stuffs. For half a century and more the aim of American railway builders has been to provide economical routes to the seaboard for the export to other countries of the surplus food products from the fertile lands of the Mississippi Valley.

During the past decade, however, our home consumption of food products has been fast overtaking production. The time is close at hand when American farms will have their productive capacity taxed to supply American consumers alone. The situation with respect to our agricultural development was recently presented to the public in a remarkably forceful way by Hon. Jas. J. Hill, in an address delivered before the American Bankers' Association, at its annual meeting in Chicago. We reprint portions of this address elsewhere in this issue as well deserving the attention of engineers. Mr. Hill points out that while we exported last year $438,000,000 worth of food stuffs we imported $329,000,000 other food. It is true the foods which we imported were largely high-priced luxuries, while our exports were principally such staples as wheat, corn and meats; yet as Mr. Hill clearly shows, the question of a food supply for our own population will soon supersede the question of an export market for our surplus.

Statistics of the Bureau of Commerce and Labor made public on Nov. 5, confirm Mr. Hill's assertions with respect to wheat exports. During the nine months ending Sept. 29, 1909, we exported less than 28 million bushels of wheat. For five years past our wheat exports have aver-

aged only 113 million bushels per annum, which is 40% less than in the five years preceding; yet more wheat was raised on the farms during the last five years than during the first.

The shortage in Europe's wheat supply due to falling off in United States exports is being made up by increased production in Argentina and Canada. The former country exported 139 million bushels of wheat last year and has taken the place of the United States as the more important source of wheat supply to Europe.

The decision of the Swiss railway administration to go back to the use of steam locomotives on the Seebach-Wettingen Ry. after two years' trial of electric locomotives was briefly noted in the contribution published on page 508 of our last issue. Later advices state that the governing reason why electric operation was finally abandoned on this particular road was that the electric operation was found to cost about $14,000 a year more than operation with steam locomotives, or something like $1,000 per annum per mile of road operated.

It has been widely stated that the entire railway system of Switzerland was eventually to be operated by electricity; and there seems good reason to believe that this has been contemplated by the railway management. As a result of the Seebach-Wettingen experience, however, it is now stated that electric locomotives will only be introduced in lines with very heavy grades and dense traffic and divisions where long tunnels occur.

To understand the importance of the decision that universal electrification of the Swiss lines is not to be undertaken, it must be borne in mind that the conditions in Switzerland are more favorable for electric operation, probably, than in any other country. Coal for locomotives is very costly and must all be imported. Waterpower for electrical development, on the other hand, is abundant and widely distributed and further, it is under such control by the Government that its use can be obtained practically at the cost of development. Switzerland has been looking forward to the time when her abundant stores of "white coal" should propel all her railway trains, and every opportunity has been given to the promoters of electric traction to demonstrate the merits of their systems. Failure to succeed under such conditions teaches a significant lesson.

London cable dispatches of Nov. 10 announce the exhibition of a full-size railway car on the gyroscope principle, invented by Louis Brennan. It will be remembered by many of our readers that some two years ago Mr. Brennan exhibited a small model of his invention, which consists, briefly, in balancing a car on a single rail by the gyroscopic force of high-speed vertical rotors on the car. Since his original demonstration, Mr. Brennan has been furnished with funds for his experiments by the British Government, and has constructed a full-size railway car 40 ft. in length, 10 ft. wide and 13 ft. high. The car weighs 22 tons and is balanced by two gyroscopes, each 3 ft. 6 ins. in diameter and having a total weight of 1½ tons. A gasoline engine on the car drives a generator, the current from which is used to propel motors on the car axles and also to run the gyroscopes. The speed of the latter is said to be 3,000 r. p. m.

According to the reports, 40 persons rode in the car and were carried up and down the single-rail line, and around sharp curves, the car being maintained in equilibrium by the gyroscopes so perfectly that when all the passengers crowded over to one side of the car, the vehicle was automatically tipped so as to bring the center of gravity above the point of support. How this remarkable result is attained has not been made public, save in the patents issued to Mr. Brennan; but those so far issued have not made clear the actual method by which the gyroscopic force is brought into play.

The ingenuity of this novel invention is admitted by every one, but its field of practical application is not yet clear. The inventor himself is quoted as claiming that his discovery will revolutionize the railway systems of the world, because he can attain a much higher speed than is possible on the ordinary two-rail railway. This claim, however, does not appeal to those familiar with the practical application of railway operation. As has been often pointed out, train speeds of present railways are limited by other considerations than the roadbed or the locomotive. Even if it were theoretically safer to run at high speeds on a monorail line than on a two-rail line (which has never been demonstrated), it is extremely doubtful whether such high-speed trains would be commercially profitable. Many well-posted railway experts believe that the highest-speed trains run on present railways involve much larger expense, direct and indirect, than their earnings will cover.

There is another possible field for Mr. Brennan's invention, and that is for lines of very light traffic and low speed, where a single-rail line could be built for considerably less cost than an ordinary railway. It is doubtful, however, whether the added complication and cost of the gyroscopic feature would not counterbalance any gains in first cost of the roadbed. As a matter of practical experience, any devices involving much mechanical complication have never had any permanent success in railway service. This is true even of the large railway systems whose rolling-stock is in charge of competent officials. When we examine the small railway companies which handle the traffic on spurs and branch lines in remote districts, we find that cars and locomotives have to get along with very crude work in the way of repairs and inspection. A gyroscope car would fare badly, for example, run on the average logging road.

The reform of our system of employers' liability laws on the basis adopted by all other industrial countries, so that the industry itself will bear the burden of accidents, is engaging widespread attention at the present time. In New York the subject is being investigated by a state commission. The state of Minnesota, also, has a commission investigating the matter, and the address of the chairman of that commission was one of the notable features at a recent convention of the insurance companies engaged in carrying employers' liability risks. The National Civic Federation, which holds its annual meeting in New York City next week, has given this subject the most important place on its program.

Perhaps the objection most commonly raised to the system is that it will involve the employer in a largely increased burden of expense. It may be of interest, as bearing upon this matter, to see what results are obtained in other countries. "The Engineer," of London, in its Nov. 5 issue reviews the recent working of the compensation acts in Great Britain. It summarizes the total amount paid out as compensation by employers in 1908 at $10,000,000 in round numbers. This may seem like a huge sum, but when the total number of employers and employees affected are considered it is actually small. A good idea of the expense involved to the British employer by the workmen's compensation laws can be obtained from the statistics which show the average amount paid out annually in compensation for injuries per employee at work. From the figures given by "The Engineer," we compile the following table:

Industry.	Average annual compensation for injury per employee at work.
Shipping trade	$2.33
Metal trades, extraction, founding and galvanizing	1.52
Engine and ship building	2.92
Mining	4.13
Quarries	1.94
Railways (not including office employees)	1.84
Woolen industry	0.18
Cotton industry	0.36
Docks and stevedores	6.08

It will be evident from the above table that the actual money outlay involved in paying for accidents to workmen the rates of compensation fixed in Great Britain is by no means a serious burden in any industry.

Another interesting fact is brought forward by "The Engineer." When the workmen's compensation acts were put in force in Great Britain, the old employers' liability laws were also left in force; so that a certain amount of accidents may still be adjusted by the old method still followed in the United States—a lawsuit against the employer. It is stated that the percentage of claims taken to court in this way is rapidly diminishing, and that the workmen and employers alike accept the new basis of settlement as vastly fairer to both parties concerned.

The annual meeting of the Railway Business Association, held last week in New York City, was notable, first, for the success which this rather unique organization has secured, and second, for the commendably broad viewpoint which its officers apparently are taking of the work before them. While the association is avowedly organized to promote a fairer attitude by the public toward the railways of the country, it has not taken the unfortunate position which was all too common among railway officers ten years ago. At that time the majority of railway officials were still insisting that railway operation was a private business and that the public had no right to interfere with it in any manner.

It is uncommon nowadays to hear such views expressed; on the contrary, railway officials everywhere freely admit that State and National regulation of railway affairs has come to stay. The officers of the Railway Business Association have recognized this and perceived that much more can be accomplished by cooperating with those in high places in the government who are seeking better methods of railway regulation, than by continuing the old attitude of mere obstruction.

We are well aware, however, that it is easier to change opinions than established policies. Various railway presidents have made frank public recognition of the right of the state to regulate the railway business; yet the old policy of appealing to the courts from the enforcement of the Interstate Commerce Commission's orders continues; and the law's delays are sufficient to practically nullify and defeat the effect of much of the Commission's work.

President Taft has suggested that a special railway court shall be created, to which appeals from Interstate Commerce Commission's orders must be taken, so that prompt decision can be secured. It is difficult to see any reasonable ground for objection to this plan on the part of the railways, if their appeal to the courts is taken in good faith, to secure justice, and not merely to interpose delay. At any rate, the proposal for a special railway court, when it comes up in Congress next session will afford railway managers an excellent opportunity to carry recent excellent professions of principle into practical effect.

Those of our readers to whom the science of geodetic surveying is a sealed mystery and who skipped in consequence the report of the International Geodetic Association meeting in our last issue, might yet be interested to learn from that report that the earth's poles are wabbling. There may be those who will hasten to seek a ray of hope in this for a certain arctic traveler. If the pole wabbled far enough he might have grasped it as it came past!

The Frictional Resistance of Steam Locomotives Running with Closed Throttle.

At the meeting of the American Institute of Electrical Engineers, on Nov. 12, Dr. Gary T. Hutchinson described the new electric locomotive system by which the Great Northern Railway Company is now hauling trains through its Cascade Tunnel. This paper contains some tests of the frictional resistance of steam locomotives which deserve the careful study of every engineer interested in railway motive power.

The Cascade Tunnel has a 1.7% grade. Up to the time when electric traction was put in operation, the trains had been hauled through the tunnel and over the steep mountain grades on the division of which the tunnel forms a part,

by huge Mallet locomotives, weighing, with tender, about 250 tons. When the electric locomotives were installed, the trains were hauled through the tunnel with the steam locomotive idle, its throttle being closed.

The test instruments on the electric locomotive when hauling trains up this grade indicated a much higher train resistance than could be accounted for by the car resistance alone, and so tests were made with the electric locomotive hauling the steam locomotive alone behind it. In this way, by deducting the friction of the electric locomotive, accurate figures were obtained for the total resistance offered by the steam locomotive when towed with closed throttle up the tunnel grade. Deducting from these figures the portion of the resistance due to grade, there was obtained the frictional resistance of the steam locomotive, and this resistance was truly astonishing. We quote the figures from Dr. Hutchinson's paper as follows:

Kind of locomotive.	Frictional resistance of locomotive, lbs.
Mallet No. 1904	10,840
Mallet No. 1911	9,000
Mallet No. 1905	15,700
Consolidation	5,480
Pacific	3,870
Electric	1,500

These figures, we understand, were no less surprising to the engineers of the railway company than they were to the electrical engineers making the test. Taken at their face value, they seem to show that an enormous part of the power developed by the steam locomotive is absorbed in its own machinery. It will be seen that the frictional resistance of one of the Mallets was nearly ten times as great as the frictional resistance of the electric locomotive.

These figures are likely to be quoted by those who seek to indict the steam locomotive as a wasteful and uneconomical machine for railway service in comparison with its electric competitor. Certainly, therefore, these figures deserve analysis, and particularly so because many previous tests of steam locomotives have shown exactly contrary results; to wit, that the steam locomotive has a small friction loss compared with the average stationary engine.

It is, of course, entirely reasonable that the frictional resistance of the electric locomotive should be somewhat less than its steam competitor, since it does not have the friction of side rods, crank pins, cross heads, pistons and valve gear; but when we make reasonable allowance for the friction of these moving parts of the steam locomotive, the results of Dr. Hutchinson's tests still remain unexplained. Let us study his figures a little and see how this great friction can be accounted for.

Taking the three Mallet engines, we find that their average frictional resistance, measured in terms of draw-bar pull, was 11,850 lbs. Let us deduct first from this the resistance of the locomotive considered as a car; that is to say, the frictional resistance of the tender, and of the driving axles and truck axles of the locomotive. The total weight of the locomotive and tender is 250 tons, and an allowance of 6 lbs. per ton would doubtless be accepted as fair for the friction of this load upon the carrying axles, including the resistance at the treads of the wheels. This makes a total of 1,500 lbs., which, deducted from the 11,850 lbs. of total frictional resistance, leaves 10,350 lbs.

Now, how much of this remainder may we assign to the friction of the crank pins, cross heads, valve gear and pistons? For guidance on this point, let us inquire what the frictional resistance of these parts is when the locomotive is under steam. Many previous tests of locomotives have shown that 10% is an ample allowance for the friction of these parts when the locomotive is working at a fairly good load. Such a load, with a locomotive of this tractive power, might be represented by a draw-bar pull of 50,000 lbs., and this would mean on that basis 5,000 lbs., friction in the moving parts of the engine. This is almost certainly very much higher than the friction when the engine is being towed idle, for under such circumstances the pressure on the valves, crank pins and cross heads, and the consequent frictional loss, must be very much less than when it is working under full steam. However, let us allow 5,000 lbs. as the maximum possible frictional loss in these moving parts. We have then still left 5,350 lbs. frictional resistance of the locomotive to account for, and the puzzle is where the force can come from that holds the locomotive back in this manner. The puzzle, however, is not difficult of solution, for, in fact, there is only one possible place where this resistance can be exerted, and that is on the pistons themselves. What is happening evidently is that the pistons of the locomotive are acting during a part of their stroke as *vacuum pumps*, and also as *air compressors*, and it is this resistance to the movement of the pistons which retards the locomotive when it is being towed with a closed throttle.

It is pretty well understood that when a steam locomotive is run with the throttle closed and the reverse lever in *back gear*, the locomotive cylinders act as air compressors. The Le Chatelier water brake, much used on mountain railways in the West, depends upon this principle for its operation; and there are other systems of braking of a similar sort.

It is not so well known that with the reverse lever in *forward gear* and the throttle closed, there is still a considerable resistance to the piston movement. The operation, however, is clear enough on a little thought. Suppose the reverse lever is in forward gear and set to cut off the steam entrance at one-fourth the stroke and to close the exhaust at three-fourths the stroke. Then after the piston has moved one-fourth the length of the cylinder, the entry of air behind it ceases and for the rest of the stroke till the exhaust opens, the piston must expand the air in the space behind it. As it approaches the end of the stroke, also, the exhaust valve closes and compression takes place. Thus there is resistance on both the front and rear face of the piston.

It will be apparent also that with the throttle closed, the piston as it starts from the beginning of the stroke can only be supplied with air by expanding the air in the closed chamber formed by the steam chests, steam passages and dry pipe. The vacuum formed in these chambers often makes trouble with balanced slide-valves and has led to the placing of automatic vacuum valves on locomotive steam chests. These valves, however, are not in general use, and even when applied, they are seldom large enough to give adequate air supply to the cylinders, with the locomotive running at high speed.

It will be noticed in the table of frictional resistance obtained in Dr. Hutchinson's tests above, that the frictional resistance of the Mallet locomotives, which are compounds with large low-pressure cylinders, was very much greater than the resistance of the Consolidated and Pacific types of locomotive, which are simple engines. This is exactly what would be expected from the conditions which we have described above. The vacuum action is comparatively small on the small diameter pistons of the simple locomotives, but becomes exceedingly important on the compound locomotives, with their large low-pressure cylinders.

It may be of interest to compute what mean effective negative pressure is required on these Mallet locomotives to produce the frictional resistance ascertained in Dr. Hutchinson's tests. The circumference of the Mallet locomotive drivers is 173 ins., and during every revolution of the drivers the pistons sweep through 64 ins. of distance, their stroke being 32 ins. It therefore follows that to produce a pound pull on the draw-bar (neglecting for the moment all friction losses) there will have to be a pressure of about 2½ lbs. on the pistons. The total area of the four pistons of the Mallet locomotive is 2,436 sq. ins., and, computing the unit pressure on the pistons required to produce a pull of 5,350 lbs. on the draw-bar, the result obtained is 6 lbs. per sq. in., approximately.

It will be evident, also, that the vacuum and compression work done by the cylinders will be greatly affected by the position of the valve gear. A very slight change in the point of cut-off, when the engine is being towed with the throttle closed, will make a very considerable difference in the locomotive resistance. It is this, doubtless, that explains the great variation shown in Dr. Hutchinson's tables in the frictional resistance of three different Mallet locomotives which are duplicates of each other.

Turning now to the practical bearing of these results on locomotive practice, it would seem that in ordinary locomotive service the resistance to the piston movement when the throttle is closed is usually a benefit rather than an injury. When the locomotive is drifting down a grade, the retarding effect of this vacuum action is so much gained in the way of braking effect. Similarly, when steam is shut off preparatory to making a stop, the braking effect of the locomotive pistons is a valuable aid. In case the braking effect is undesired, it can be largely overcome by moving the reverse lever into full gear forward, and the engineer often does this if he has far to run with the throttle closed. Conversely, if it is desired to produce as great a braking effect as possible by using the pistons as vacuum pumps, the lever should be moved back to the shortest point of cut-off.

It will be evident, however, that the braking effect cannot be eliminated by lengthening the cut-off unless there is an ample vacuum valve upon the steam chest to furnish a supply of air to the cylinders.* It is doubtful whether the present valves applied for this purpose are anything like sufficient. One objection which may be raised to putting the engine in full gear, or to any other means of giving free entry of air behind the piston, such as applying vacuum valves to the cylinder itself, would be that the forcing of air through the exhaust nozzle when the engine is drifting tends to force the fire just at a time when it is not needed. This may be better, however, after all, than running with a vacuum in the cylinder, which tends every time the exhaust is open to suck back cinders and ashes from the exhaust nozzle into the valves and cylinders.

We have discussed this matter at some length because it is important that erroneous ideas as to the power lost by friction in steam locomotives should not gain currency. The frictional resistance of a locomotive may be high when run with a closed throttle; but it does not at all follow that its loss in friction is high when it is using steam. It ought to be more generally understood by railway engineers that whenever a locomotive is running with the steam supply cut off, its cylinders must be acting either as vacuum pumps or as air compressors. When working as compressors it has long been common to utilize the work done for braking purposes and the same thing may be done with the cylinders acting as vacuum pumps, by proper manipulation.

*Engine runners frequently open the throttle "a wee crack" when their engines are drifting. This gives enough steam to break the vacuum and keeps the boiler pressure from rising to the blowing-off point.

LETTERS TO THE EDITOR.

An Excellent Month's Work for a 20-in. Hydraulic Dredge.

Sir: On the New York State Barge Canal there are many contracts embracing work which can be successfully handled by hydraulic dredges. At present there are ten hydraulic dredges working on the construction of this canal. Some of these dredges have made very good records, others have proved to be expensive experiments, largely due to two reasons—improper design of parts of the plant, and attempts to excavate material which cannot be successfully excavated by the ordinary type of hydraulic dredge.

In November, 1908, the Kinser Construction Co. was awarded Contract No. 46, which was generally considered good hydraulic work. This contract is located about thirty miles west of Syracuse and is about ten miles long, extending through what is known as the "Montezuma Marshes." The State's engineers estimated the amount of excavation as approximately 5,000,000 cu. yds. About one-half of the contract is to be excavated through the marshes, flag or wood land, and the other half is in the Clyde and Seneca River channels.

The company decided to construct a 20-in. dredge for this contract and began work on the hull February 20, 1909. This dredge ("Montezuma") was completed and began work June 14, 1909. During the months of July and August the dredge did exceptionally good work

for a new machine, and during the month of September, 1909, excavated 480,000 cu. yds.

During September the dredge was working through a section which had recently been cleared of dense swamp forest, the stumps had been pulled and removed, and all roots and undergrowth cleaned up and burned. The cut averaged about 175 ft. wide on top, and 130 ft. wide on the bottom and 19 ft. deep, average depth of water 14 ft. The first 4 ft. on top was muck or peat, below that 5 ft. to 10 ft. of marl and beneath that sand and occasionally some hard clay on the bottom. In places the sand was very fine and heavy and densely packed, and on the spoil banks resembled quick sand. The average length of pipe line was 1,000 ft.

The following is a list of stops or delays and their causes:

4 Sundays, general repairs	96 hrs.	
Pontoons	14 "	50 min.
Swinging wires	13 "	35 "
Cleaning pump and suction	39 "	05 "
Connecting up new lines	4 "	05 "
Shore-dykes, changing valves, etc.	2 "	50 "
Boilers—replacing tubes	32 "	55 "
Repairing swinging engine	11 "	10 "
Swinging engine-gland	1 "	35 "
Main engine	0 "	20 "
Cutter engine	0 "	10 "
Backing up for "cave-in"	1 "	00 "
Total delays	217 hrs.	35 min.
Actual running time	502 "	25 "
Total hours in month of September.	720 hrs.	00 Min.

The actual excavation for this period was 480,000 cu. yds. The State's engineers estimated for the month 456,000 cu. yds., but their estimate was taken a little before the end of the month and also a small amount of material was excavated beyond or outside the required lines. The largest amount excavated in one calendar day was 28,600 cu. yds. on Sept. 20, actual running time, 20 hrs. 10 min.

A general description of the dredge might be of interest to those interested in hydraulic dredging:

HULL.—Wood, 117 ft. long, 35 ft. wide, 8 ft. 6 ins. deep.
MAIN ENGINE.—Triple expansion, 13-22¼-34, 18-in. stroke, 160 r. p. m.; steam pressure 175 lbs., direct connected.
PUMP.—Cast steel, face liners, closed runners, 7 ft. dia.
BOILERS.—Water tube, 5,000 sq. ft. heating surface.
SWINGING ENGINE.—Five drum, Mundy hoist, 10 × 12-in. swinging drums equipped with steam frictions.
CUTTER ENGINE.—Simple, two cylinder, horizontal, 12 × 12 ins., reversible, drive through ladder trunnion.
SURFACE CONDENSER.
STEAM reduced to 100 lbs. pressure for all engines except main engine.
LADDER.—47 ft. long.
SUCTION.—Pipe through trunnion.
CUTTER.—Open end, 80 ins. dia. at back, 60 ins. dia. at front, 5 ft. long, blades, manganese steel riveted to cast steel back ring and hub, cutter was special design for this material.
SPUDS.—Yellow pine, 22 ins. dia., held in cast steel spud wells and raised from steel gantry frame.

The machinery and plant was designed by the writer, and furnished by the Morris Machine Works, of Baldwinsville, N. Y. The hull was built by the Kinser Construction Co. on the site of the work.

Yours very truly,
Pitson J. Cleaver, Assoc. M. Am. Soc. C. E.
Montezuma, N. Y., Oct. 30, 1909.

A STUDY OF FARM WATER-SUPPLIES in Minnesota, made by Messrs. Karl F. Kellerman and H. A. Whittaker, of the U. S. Department of Agriculture, in cooperation with the Minnesota State Board of Health, is thus summarized by the authors in Bulletin No. 154, U. S. Bureau of Plant Industry:

(1) Both farm and city are suffering from the careless management of rural sanitation.

(2) Previous investigations of rural water-supplies have been more or less unsatisfactory, due either to the local or fragmentary character of the investigations or to the use of a single method in studying the supplies in question.

(3) Exhaustive data upon 79 carefully selected and typical rural water-supplies show that 20 were good and, usually because of careless or ignorant management, that 59 were polluted.

(4) Of the polluted wells, 11 are so located that even extreme care would not make them safe; 10 are poorly located, but improvements in the protection from surface wash and infiltration would make them safe; 25 are bad only because of poor surface protection and could easily be made safe; 1 is polluted from unknown, probably distant, sources. One spring supply is polluted because of poor surface protection and could easily be made safe. The rivers, surface reservoirs, and cisterns are polluted, and it is doubtful whether satisfactory supplies can be secured for farm use from such sources. Where their use is necessary, water for drinking should be boiled or otherwise disinfected.

(5) During this investigation 23 of the farms examined showed a record of typhoid fever. On 11 of these farms, it was found impossible to locate the source of infection, on 2 farms possible sources were determined, while on 10 the data seemed to locate definitely the source of infection. The water-supplies upon 5 of these farms were not polluted and the infection was traceable to outside sources; the water-supplies of the remaining 18 farms were polluted.

(6) The protection of farm supplies by common-sense methods obvious to any one who will try to discover the dangers incident to his own water-supply would render safe the majority of the farm supplies which are now polluted. Exhaustive studies of rural conditions at the present time, therefore, are warranted only in connection with epidemiological studies.

The Shield Method Applied to Sinking Building Footings; Chicago & Northwestern Terminal, Chicago.

In the construction of the new terminal station of the Chicago & Northwestern Ry. at Kinzie and Wells Sts., Chicago, Ill., it was necessary to carry some 87 footings down to solid rock. At this site the first 10 or 15 ft. below curb level is a filling of refuse material of various kinds deposited after the Chicago fire. Below that is about 60 ft. of heavy blue clay, soft near the top but quite stiff as it approaches the next lower layer of hardpan, which is from 10 to 20 ft. thick. Below the hardpan is a stratum of water-bearing material 20 to 30 ft. thick and varying downward from sand through gravel to the boulders which rest on the solid rock about 120 ft. below street level. In starting the construction of these footings, the ordinary open caisson method was employed. Six footings along one side of the lot were driven in open cofferdam without much difficulty until the bottom of the clay layer was reached. On approaching the layer of water-bearing gravel, water began to come in so fast, in spite of strenuous pumping and extraordinary sheet-piling, that another method of operation had to be sought.

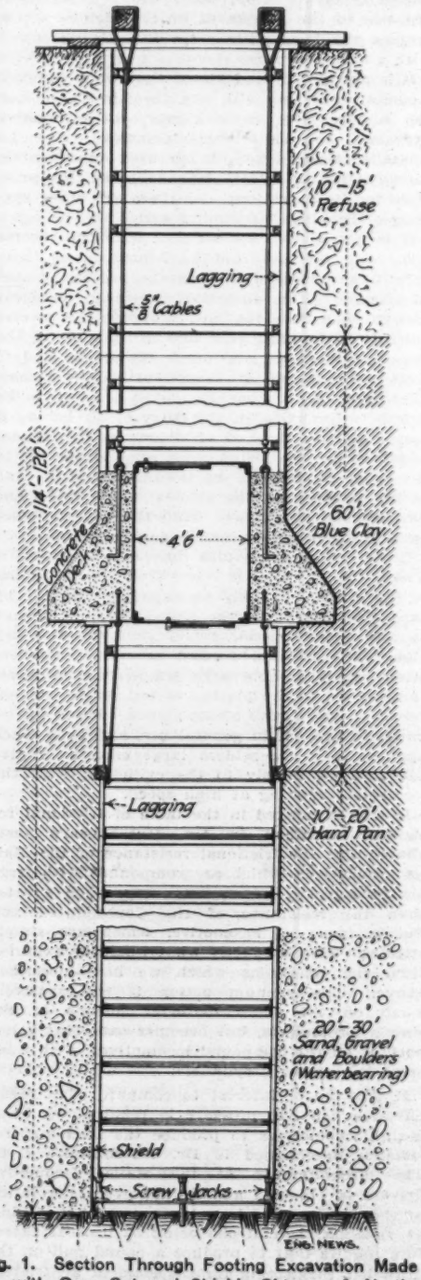

Fig. 1. Section Through Footing Excavation Made with Open-Cut and Shield; Chicago & Northwestern Ry. Station, Chicago.

This new method, which was used on the six footings mentioned and then on the 81 remaining with great success, is merely an application to vertical shaft sinking of the familiar shield method of tunneling. The first 80 ft. or [illegible] shaft was sunk by ordinary open caisson below that point a shield was attached to bottom of the cofferdam, a compressed-air lock was installed and the remainder of the depth excavated under compressed-air, the shield being jacked down and lagging placed as excavation progressed. When rock was reached 40 ft. farther below, the hole was filled up solid with concrete to the surface, leaving a solid concrete pillar to transmit the load from footing to rock.

The accompanying cuts and view will serve to illustrate the system in its final development on the work; numerous improvements were, of course, made over the methods used on the first footings. Caissons were excavated in groups of six to ten, placed in such manner that the removal of spoil would be most economical. In the shaft, excavation would proceed in open cofferdam, circular in section to a point about 10 ft. above the bottom of the clay. At this point the pit was excavated to a diameter 3 ins. larger than the outside diameter of the shield, which was itself some inches larger than the timber cofferdam circle. In this widened excavation the shield was set up, bolted together, sealed with clay and a little grout back-filled, and four 10-ton jacks adjusted around the circumference, between the bottom of the cofferdam and the cutting-angle on the shield. Lagging was then placed connecting the bottoms of the shield and the cofferdam.

About 10 ft. above the bottom of the open excavation, a section of the lagging to the cofferdam was removed and the material outside excavated for a distance back of about 2 ft. and for a depth of 6 ft. Into this space concrete was placed, holding tight the air-lock which was of steel, 4½ ft. in diameter and 5½ ft. high. This was an ordinary air-lock, provided above and below with doors and with proper pipe connections. Into this concrete around the lock 1-in. eye-bolts were placed, projecting above and below on a circumferential line around the lock. Through the upper of these bolts, ⅝-in. cables were run up to supporting timbers at the top of the shaft, as a safety precaution. From the lower bolts, ½-in. round rods were suspended and to them the lower lagging was connected to prevent an upward movement of the lock. These details are all shown in Fig. 1.

The shaft was now in condition to allow excavation to proceed under pressure. As the shield was forced down by jacking against the upper timbers, sections of circumferential lagging were placed, until the bottom was reached.

The shield used in the work is shown in detail in Fig. 2 and in the view in Fig. 3. It consisted of a cylinder of ⅜-in. steel, 5 ft. 11 ins. in inside diameter and 3 ft. 5 ins. high. This cylinder is made up of four quadrant sections. One vertical edge of each of these sections has riveted to it a ½-in. butt strap, which laps over the edge and contains a row of partially punched threaded holes, which in the joining of the sections, receive tap screws through corresponding holes in the vertical edge of the adjacent section. The shield can thus be let down into the shaft in four pieces and there be tap-screwed into the complete cylinder. For a cutting edge, a stiffener and a brace against which the jacks can act, a 4 × 4 × ½-in. angle is riveted around the bottom circumference of the cylinder.

The lagging below the air-lock was made up of 2½-in. tongue and groove boards in 3-ft. lengths. It was assembled in four quadrant sections, in each of which the lagging was bolted top and bottom to the vertical legs of circumferential angles, which were bolted together with straps into the complete circumference. These 3-ft. sections were bolted together in the shafts by bolts through the horizontal legs of the lagging angles. Fig. 3 shows two quarter sections of both the

shield and the lagging sections, bolted together to form a half circumference. The position of the jacks is also shown.

Air was brought to the caissons through a 2½-in. pipe to a point about 6 ft. above the shield cutting edge. This was found necessary owing to the difficulty in keeping the lagging air tight

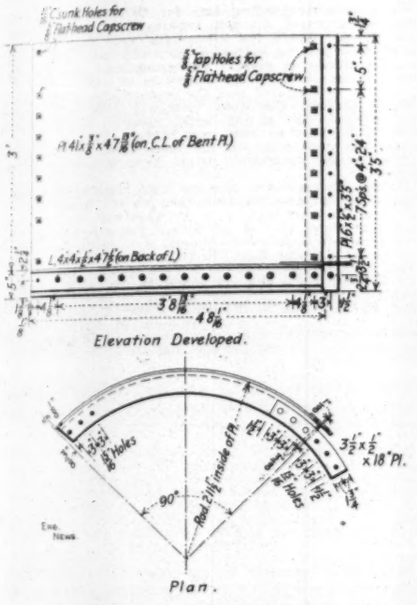

Fig. 2. Details of Shield.

when the air was taken in just below the lock. The dry air, coming in at the top, seemed to dry out very quickly the mud used to plug up the lagging. When the shield finally reached bottom, the bolts in the angle at the cutting edge were removed and the angles there recovered. In most of the caissons it was impossible to recover the shield. Concrete was then shot down in chutes to the top of the lock and lowered by bucket to the bottom as rapidly as possible. As the concrete rose each set of bracing angles in turn was unbolted and removed, leaving the timber lagging in place. At all times, then, this lagging was safely braced, either by the angles or by concrete. When the concrete reached the lock, it too was collapsed by removing a key placed for that purpose and the pier continued to the top. A 1:3:4 mixture of concrete was used.

Practically the only difficulty with the work was the very free escape of air through the material overlying the rock. This escape was so marked that evidences of the air were noticed in other open-caisson excavations about ½-mile away from the station site.

The caisson foundations were put in for the Chicago & Northwestern Ry. by The Foundation Co., 115 Broadway, New York. We are indebted to this latter company for the information and illustrations from which this article was prepared.

LONG REINFORCING RODS are being used in the arches of a concrete bridge under construction at Cedar Rapids, Iowa. It is a highway bridge with seven spans of 80 ft., and the longitudinal reinforcement in the top and bottom of the arch consists of 1⅛-in. rods 94 ft. long, thus avoiding splices. Each rod has threaded ends, with a nut and anchor washer on each end. The arches are of 1:2:4 concrete, and are 18 ins. thick at the crown. The bridge is 40 ft. wide, with a roadway and two 6-ft. sidewalks. It is designed to carry a street subway line, but this has not yet been built. The foundations are carried to rock, through 8 to 16 ft. of sandy gravel. The concrete pier foundations were at first built within sheet piling driven at the neat lines of the foundation, but there was trouble with water entering. For the other piers, the piling was driven 2 ft. outside of the neat lines, and a form built on the latter, so that any water entering would simply occupy the space between the piling and the form. Steel sheet piling was used at the deeper foundations. The bridge was designed by Mr. I. G. Hedrick, of Kansas City, Mo.; and Mr. W. A. Hoyt, of Chicago, was Superintendent of Construction.

The Calumet Drainage Channel of the Chicago Sanitary District.

The construction of the Calumet Drainage Channel, from Lake Michigan (by way of the Calumet River) to the Chicago Drainage Canal, is likely to be undertaken soon by the Sanitary District. At present, however, the only work being done in connection with this project is the improvement of the old Calumet feeder, which will serve as a drainage ditch during the construction of the channel. It is expected that the channel will be built of small dimensions, with a capacity of probably about 2,000 cu. ft. per sec., in view of the suit between the Sanitary District and the War Department regarding the quantity of water that may be diverted from the lake. If the District wins the suit, the channel will be enlarged when necessary. Otherwise it will remain of small capacity.

The construction of this channel as a means of preventing the pollution of Lake Michigan is considered as an essential part of the work of the Sanitary District, regardless of the outcome of the suit noted above, the main bearing of this suit being upon the quantity of water to be diverted (and consequently the capacity of the channel). In view of the importance of the Calumet channel as an auxiliary to the Chicago Drainage Canal and in relation to the purposes of the Sanitary District, we give herewith an abstract of a report made in June by Mr. G. M. Wisner, M. Am. Soc. C. E., Chief Engineer of the Sanitary District. The controversy between the Sanitary District and the War Department and the evidence as to the effect of the proposed Calumet Canal upon the levels of the Great Lakes, were reviewed in our issue of May 27. A very full description of the Chicago main drainage canal and its auxiliary channels (and other works), by Mr. Isham Randolph, M Am. Soc. C. E., was published in our issue of July 22.

Report on the Calumet Drainage Channel.

At the time of the annexation of the Calumet District to the Sanitary District of Chicago, it was the plan of the Engineering Department of the District to construct, through the Sag Valley, a canal from the Calumet River (east of Blue Island) to the Main Drainage Canal. This canal was to have a capacity of 4,000 cu. ft. of water per sec.

This project of taking additional water from Lake Michigan was opposed by the International Waterways Commission, which reported to the Secretary of War and recommended that the amount of water taken by the Sanitary District should be limited to 10,000 cu. ft. per sec. This was approved by the Chief of Engineers. The matter was then taken up by the Sanitary District with the Secretary of War, who refused to grant a permit to take this additional water, but agreed to a law suit to establish whether or not the Sanitary District had the right to take the additional water from Lake Michigan without a permit from the Secretary of War. In the fall of 1907, the Sanitary District started the work of construction of the Sag Canal and the government applied for an injunction restraining the District from taking the 4,000 cu. ft. additional. Testimony in this case has been and is being taken before a commissioner, and it will probably be several months before a decision is reached.

The discharge of all of the sewers south of 87th St. into the Calumet River and the growth of the population of this territory, covering 95 sq. miles, has developed conditions which are quickly growing intolerable. Hence the Engineering Department has, during several months, given considerable study to the conditions obtaining in this district. The filth coming from the sewers settles in the Calumet River and is periodically flushed into Lake Michigan in times of freshets, thus contaminating the water supply of Chicago.

Since the starting of the government suit, this department has aimed to develop some project which would adequately take care of the Calumet District whether or not the Sanitary District is allowed to take the 4,000 cu. ft. per sec. additional. The problem therefore is to take care of the sewage of Chicago and the Calumet District with 10,000 cu. ft. per sec., diverted from Lake Michigan, and also with 14,000 cu. ft. per sec. diverted from the lake. It has been borne in mind also to have the sewage diluted locally as much as possible; that is, that the sewage coming into the branches of the Chicago River, and also into the Calumet River, should have water from the lake sufficient to dilute it, so that at no place within the whole district would the waters of these rivers be obnoxious.

Three principal problems were encountered in the study of the Calumet District: (1) to keep the sewage of this district from discharging into the lake; (2) to keep the Calumet River which (even without sewage) is in a more or less polluted state, from discharging into the lake as far as is practicable; (3) that all work done should be along navigable lines.

(1) The problem of keeping the sewage from the lake at all times during the year is an expensive one, requiring the building of several miles of intercepting sewers, either carrying the sewage to a canal which would discharge into the Main Drainage Canal, or carrying the sewage to purification plants which would render the effluent innocuous, the effluent being discharged into the Calumet River. The construction of these intercepting sewers involves an expense of over $2,000,000.

(2) On account of the large floods of the Calumet River in times of freshets, when the discharge (at times) reaches 16,000 cu. ft. per sec., it is not practicable to divert the entire flood waters of this district to the Drainage Canal at Sag, as this amount of water discharging into the canal at this place would crowd the Chicago River waters into the lake and would much exaggerate the flooding and overflow conditions of the Illinois River.

The largest discharge that could safely be taken through the Sag Valley canal would be in the neighborhood of 4,000 cu. ft. per sec. The maximum floods of the Calu-

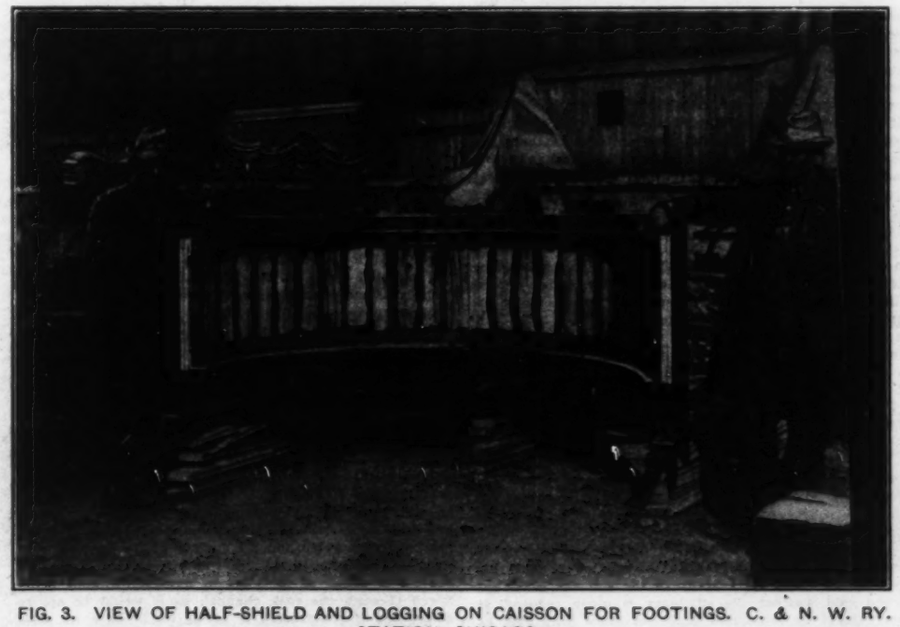

FIG. 3. VIEW OF HALF-SHIELD AND LOGGING ON CAISSON FOR FOOTINGS. C. & N. W. RY. STATION, CHICAGO.

met River can be somewhat reduced by the construction of a channel connecting the Little Calumet River with Lake Michigan east of Dune Park, Ind. It would seem that this would be a desirable condition, as it would reduce the quantity of water to be discharged into the lake at the mouth of the Calumet River, which is within about four miles of the 68th St. water intake.

A stream such as the Calumet River, which passes through a densely populated district, is always a source of danger to a water supply, even if the sewage of the community is not discharged into the river, for the reason that in spite of all precautions that can be taken, the river becomes more or less polluted, especially in the dry weather months when the stream for several months at a time is practically stagnant. At such times, deposits accumulate which are scoured out later by freshets.

(3) In considering the different projects that have been proposed and studied, a preference has been given to those which will ultimately aid in the development of inland navigation.

DIVERSION OF 10,000 CU. FT. PER SEC.—Under the diversion of this amount of water from Lake Michigan, three principal projects have been developed.

(1) A canal through the Sag valley capable of carrying 2,000 cu. ft. per sec., with intercepting sewers conveying the sewage to the beginning of the canal just east of Blue Island, where the sewage will be discharged west of controlling works. Under this project, 7,000 cu. ft. per sec. will be brought through the Chicago River, and 1,000 cu. ft. per sec. through the 39th St. conduit.

(2) A canal through the Sag capable of carrying 1,000 cu. ft. per sec.; intercepting sewers the same as above, with 8,000 cu. ft. per sec. of water coming through the Chicago River and 1,000 cu. ft. per sec. through the 39th St. conduit.

(3) Purification plants to take care of the sewage of the Calumet District; 8,000 cu. ft. per sec. to be brought through the Chicago River and 2,000 cu. ft. per sec. through the 39th St. conduit.

DIVERSION OF 14,000 CU. FT. PER SEC.—For this diversion, several projects have been considered, and all but two have been discarded on account of their impracticability or great expense.

(4) A canal through the Sag of 2,000 cu. ft. per sec. capacity, to be increased to 4,000 cu. ft. at such time as the population of the Sanitary District shall have reached 3,600,000 (probably in the neighborhood of 1929). Under this project 8,000 cu. ft. per sec. would come through the Chicago River, and ultimately 2,000 cu. ft. through the 39th St. conduit.

(5) Same as (4) with the exception that a canal of 4,000 cu. ft. per sec. capacity would be built immediately.

PURIFICATION WORKS.—There have been several articles written, both by engineers and laymen, advocating that the sewage of the Calumet District be treated by purification plants. In these articles it was contended that as the first cost of the purification method was less than the first cost of any canal scheme, therefore the purification method should be adopted.

But the advocates of this process of sewage disposal neglected to compare the different projects on their annual costs, rather than upon their first cost. If this had been done they would have discovered that the canal project within a short time would be cheaper to the community than any sewage disposal project. In all of the schemes proposed for the treatment of sewage by purification works, the effluent of these plants was to be discharged directly into the Calumet River and thence into Lake Michigan. None of them have stated or are willing to claim that the effluent from septic tanks, in combination with sprinkling filters or contact beds, will be sufficiently purified without some after treatment by means of sand filtration or chemicals to such a degree as to be harmless when discharged into the water supply of a large city.

The construction of sand filters for the treatment of the effluent of a sewage disposal plant for the Calumet district would occupy so much space and be so expensive as to be almost prohibitive. The most recent sewage disposal plant constructed in this country is at Columbus, Ohio. This plant consists of septic tanks, the effluent of which is conveyed by pipes and sprinkled on beds of crushed stone. The effluent of these sprinkling filters is then allowed to settle in a large tank and afterwards discharged into the river. The information is that this plant works fairly successfully in the summer time, but during cold weather its efficiency is much reduced, it being stated by some that it is not more than 50% as efficient then as in the warmer months. A disposal plant of this kind requires constant attention and maintenance and if it is not properly operated, the effluent soon becomes dangerous.

At Baltimore, where it is proposed to treat the sewage in order to protect the oyster beds, it is proposed to use not only the septic tanks and sprinkler filters, but to treat the effluent afterwards by means of sand filtration or some after treatment. If this method is necessary to protect oyster beds located some 15 or 16 miles from the source of the pollution, it certainly will be necessary to protect the drinking water of a large city where the intake is within four miles of the source of the pollution.

NECESSITY FOR A DRAINAGE CANAL.—As stated above, a river that is practically stagnant during several months of the year, and that passes through a large manufacturing district, will become badly polluted even if the sewage is diverted from it. In my opinion, to keep the river from becoming obnoxious and dangerous it is necessary to set up an artificial current to take the waters of this river away from the water supply during the low-water season. By this means the pollution and sediment will be carried away, and only a very small percentage of it will find its way into the lake in times of freshets.

Several of the most prominent engineers of this city have been consulted in regard to this matter, and it seems to be the consensus of opinion of those that are unbiased that a canal of some size should be built connecting the Calumet River with the Drainage Canal at the Sag, even if sewage disposal plants be constructed in order to prevent the river from becoming highly polluted during the dry weather season.

This opinion is shared and advocated by the Engineering Department of the Sanitary District and it only remains to determine what size of canal will be the most beneficial, taking into consideration the expense of the different projects. Canals of 1,000, 2,000, 3,000 and 4,000 cu. ft. per sec. capacity have been considered and the cost estimated. The accompanying table gives (1) the number of days in the year that the Calumet River (with the designated canal built) would discharge into the lake, (2) the number of days that the river would be practically stagnant, and (3) the total number of days when the river would be either stagnant or discharging into the lake:

EFFECT OF A CALUMET CANAL UPON THE CALUMET RIVER.

Canal capacity, cu. ft. per sec.	Cost.	No. of days. River flow into lake.	River Stagnant.	Total.
1,000	$4,516,000	101.5	83	180
2,000	6,228,000	22.4	8	30
3,000	8,178,000	9.8	6	16
4,000	11,073,000	5.5	1.3	8.8

From this table, it will be seen that with a canal of 1,000 sec.-ft. capacity the river would discharge into the lake 101.5 days and be practically stagnant 83 days, whereas with a 2,000-sec.-ft. canal there would be only 22.4 days during the year when the river would discharge into the lake and eight days when it would be stagnant. This latter condition is very favorable as these freshets are periodical, and, with the current of the river flowing in the opposite direction for the remainder of the year, the river would not become noisome or dangerous, as would be the case with a 1,000-sec.-ft. canal.

From this table it becomes evident that the 2,000-sec.-ft. canal is more than worth the difference in cost between the 1,000 and 2,000-ft. canals (about $1,700,000). This 2,000-sec.-ft. canal also has one further advantage in that about $40,000 per annum (which, capitalized, means about $1,000,000) can be saved, inasmuch as only one pump at the 39th St. pumping station need be operated under the 10,000-sec.-ft. diversion from Lake Michigan. Under the 14,000-sec.-ft. diversion it need be operated only for a short period after the population of Chicago reaches about 4,000,000. The operation of the one pump will maintain the South Fork of the Chicago River in a good condition, provided that this arm of the river is not polluted more in the future than it is at present. This is a matter that can be controlled easily.

NAVIGATION.—The 2,000-sec.-ft. canal is 20 ft. deep and 36 ft. wide on the bottom, with side slopes of 1 on 2; through the rock section it is of the same depth and 60 ft. wide. The argument may be presented that it is not as navigable a channel as the one of 4,000-sec.-ft. capacity. But when it is considered that even the latter will not be navigable to a practical extent by any modern lake vessels, the problem resolves itself down to one of barge or lighterage navigation. A boat with 56 ft. beam and 19.6 ft. draft, on a 4,000-sec.-ft. canal, could safely make a speed with the current of only 3.86 mi. per hr. in the earth and about miles in the rock. Against the current, it could only make a speed of about 1 mi. per hr. in the earth and 3.4 mi. per hr. in the rock sections. In addition to this, it would be extremely hazardous for a vessel of this size to navigate without being towed through the rock channel, as it would be apt to sheer, and if constructed of metal would have its sides stove in. In this connection I wrote to Mr. Alfred Noble, M. Am. Soc. C. E., and he stated as follows in reply to my letter:

I agree with you that the cross-sections are too small for safe navigation of vessels of the size now in use. The area of cross-section of the larger type of freight ships now in use might be taken as from 1,000 to 1,200 sq. ft., which would occupy about half of the cross-sections. You can see at once that the speed of a boat moving against the current would be limited in the earth channel to 2½ to 3 miles an hour in order not to create currents strong enough to erode the banks while the ship is passing.

Curiously enough, the suggested section in each is the same as in the Suez Canal when first built. As showing the risks to ships passing through such a channel, we have information to the effect that in the Suez Canal in 1886, before the enlargement and while the bottom width was still 72 ft., 6.1% of the total number of ships passing ran aground. These delayed other ships, to the amount of 9% of the number passing. In other words, [illegible]% of the ships passing through the Suez Canal in 1886 were delayed either by themselves grounding or being obliged to wait because the channel was choked by grounded ships.

We have corresponding data for 1904 through the 20 miles of excavated channels between Lake Superior and Lake Huron, where the groundings were only [illegible]% of the number passing, although the traffic was almost exactly six times as great. The groundings depend very much, of course, upon the congestion of traffic. It must further be remembered that the average size of the ships passing through the Suez Canal in 1886 was much smaller than that of the larger class of lake vessels. With such ships as now pass through the St. Mary's River, the groundings in the Suez Canal at the time and under the conditions, would have been very much greater.

The foreign engineers, who are much more easily reconciled to the narrower channels than we are, have a rough rule that the cross-section of the waterway should be at least four times that of the ship. For safe navigation, particularly in a crowded channel, it is believed on this side of the Atlantic that the ratio should be very much larger. On the basis of the foreign opinion, the largest ship in your earth channel would be one with a cross-section of 638 ft., corresponding with a vessel of 31 ft. beam and drawing 20 ft., or what would be perhaps a more reasonable proportion, a beam of 40 ft. with a draft of 16 ft. As you know, vessels of this kind are not economical freight carriers and are going out of use on the lakes very rapidly.

I also took up this matter with the engineers in charge of the Georgian Bay Ship Canal, and the opinion expressed by them was as follows:

Without a current the large vessels could navigate this canal at 4 to 5 miles per hour, but they could not run under their own steam. Even if the canal sides were channeled smooth, the boat would be banged and dinged, but it could be towed through with perfect safety. A canal of 72 ft. bottom in earth with 1 on 2 slopes would allow of towing, but a large boat under her own steam would be liable to sheer and run up on the side slopes.

The opinion seems to be prevalent that a canal such as has been proposed of 4,000 sec. ft. capacity through the Sag Valley will be a navigable channel for the large lake steamers. But the best that could be hoped for in a channel of this size would be for navigation of canal barges or vessels drawing from 10 to 14 ft. of water, although it would be possible to tow vessels of larger size through such a channel. The channel is altogether too small for free navigation of ships of the size of modern lake vessels. However, it is not necessary for sanitary reasons to build a larger canal at this time than one of 2,000 sec. ft. capacity. If in the future it is deemed advisable to increase the size of the canal to make it navigable, a right-of-way may be obtained wide enough so that the size of the channel could be increased.

SUMMARY.—In regard to annual cost, project No. 3, which contemplates the purification of sewage in the Calumet District, is the cheapest. But this means that the effluent from the disposal plants will be discharged into the Calumet River without sand filtration or other after treatment and be carried into Lake Michigan. This is a condition that should not be allowed, at least until the science of sewage purification by artificial methods is further advanced. As stated previously, the cost of a 2,000 sec.-ft. canal is more than worth the difference between that and a 1,000 sec.-ft. channel, and when the cost of operating the 39th St. pumping station is taken into consideration there is practically no difference in the cost of the two projects.

In all three projects (1), (3) and (4), partial purification or purification of the sewage of certain localities will have to commence about 1922 and be continued thereafter, as the population of Chicago is estimated to reach the three million mark about that year.

In case the Sanitary District wins the suit with the Government and is allowed to divert 4,000 cu. ft. per sec. additional water from Lake Michigan, no purification or partial purification will be needed until the population of the Sanitary District reaches 4,200,000, which it is estimated will occur about 1942. It is found after careful study and many estimates that it will be much cheaper to build at first a canal of 2,000 sec.-ft. capacity which (with the Chicago River improvement completed) will take care of the population of Chicago until about the year 1929, when the Sag Valley canal will have to be increased in size to 4,000 sec.-ft. capacity.

It is found upon comparing the estimates that the saving in first cost by first building a channel of 2,000 sec.-ft. capacity is a little over $5,000,000. If this sum is placed at compound interest at 4% until 1929 (when it becomes necessary to increase the capacity of this channel) it will produce $4,780,000. This sum put at interest at 4% will net an annual income of $191,000. So that although the actual annual cost, after 1930, of maintaining and operating the channel, which is first built of 2,000 sec.-ft. capacity, and then increased to 4,000 cu. ft. capacity in 1929, is about $35,000 greater than the annual cost of Project (4), the ultimate cost is much less. If a canal is built of 2,000 sec.-ft. capacity there is an annual saving of $191,000, due to the fact that the

entire expenditure is not made upon this improvement until about 1929, so that actually the first building of a small canal, and then increasing it in size, produces a saving after 1929 of about $150,000 per year.

There has been only one very difficult engineering problem in connection with developing a scheme which would answer whether the Sanitary District wins the suit with the Government or loses it. That is the regulation of the flow through the two canals (the Calumet or Sag channel and the present main drainage channel). Fortunately, it so happens that with the stretch of canal from Chicago (Robey St.) to Summit as it now is, the fall or the slope of the water surface from Robey St. to the Sag with 8,000 cu. ft. per sec. flowing is practically the same as the fall will be from Robey St. to Sag, with a flow of 10,000 cu. ft. per sec. of lake water,* with the channel widened to this capacity.

The result of this is that even without the construction of regulation works in the present main drainage channel east of the Sag, a channel can be built through the Sag Valley which will carry 2,000 cu. ft. per sec., while the present channel with the Chicago River improved will carry 8,000 sec.-ft. This same channel through the Sag will continue to carry approximately 2,000 sec.-ft. when the present main channel is widened. However, better control of the flow of two channels would obtain if regulating works were to be built in the main channel somewhere this side of the Sag.

It would seem, therefore, that it is advisable, if this district is to receive the relief that is necessary and urgent, that a channel of 2,000 sec.-ft. capacity should be built, connecting the Calumet River with the main drainage canal, whether the suit with the Government is won or lost, as this project will answer in either case. Immediate steps should be taken to secure the necessary right-of-way for a channel of this size and character. The right-of-way should be wide enough to take care of future possible widening, and the spoil be so placed as not to interfere with the increasing of the capacity of this channel at some future time.

*In times of excessive rains, as much as 12,000 cu. ft. per sec. has flowed. This was possible as the water came into the river and canal at various points east of Summit and consequently there was not so much slope required as there would have been had all of the water come from Lake Michigan.

The Three-Phase Electric-Traction System of the Great Northern Railway Company at Cascade Tunnel.*

By CARY T. HUTCHINSON,† M. Am. Inst. E. E.

The first three-phase installation on a trunk line railway in the United States was put into operation early in July of his year in the Cascade tunnel of the Great Northern Ry., about a hundred miles east of Seattle, Washington.

The Great Northern Ry. crosses the Cascade Mountains through a tunnel 13,873 ft. long. This tunnel is on a tangent and has a uniform gradient of 1.7%. Rising to the tunnel from Leavenworth, on the east, the ruling grade is 2.2%, and 21% of the total distance of 32.4 miles from Leavenworth to the tunnel is on the ruling grade. From Skykomish on the west to the summit the ruling grade is 2.2%, and 44% of the distance of 24.8 miles is on the ruling grade. The operation of the tunnel with steam locomtives has been at all times difficult and frequently very dangerous on account of the heat and smoke from the locomotives. Crow's Nest coal, which is exceptionally free from sulphur and gas-forming materials, was used for the tunnel service. It was the custom to clean the fires of each locomotive and to put on just sufficient coal to carry it through the tunnel. The rails became very wet from condensed steam, and were frequently covered with a layer of coal soot and ground sand, making them very slippery. The temperature in the locomotive cab was almost unbearable, rising at times as high as 200° F. Under ordinary circumstances it required from 20 minutes to an hour for the tunnel to clear itself of gases, but on days when the wind was changeable, the passage of the gases from the tunnel would be stopped by the change in the direction of the wind, and they would pocket. Under such circumstances, work in the tunnel was very dangerous. There are refuge chambers containing telephones every quarter of a mile, but it was a difficult matter to keep these instruments in order, on account of the gases, smoke, and moisture.

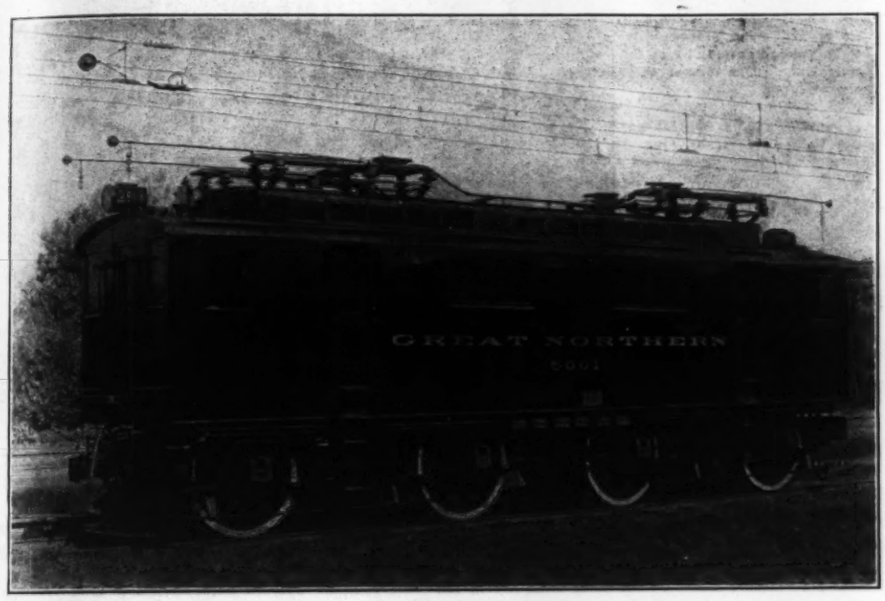

FIG. 1. GREAT NORTHERN THREE-PHASE ELECTRIC LOCOMOTIVE.
(Built by the General Electric Co., Schenectady, N. Y.)

*Extracts from a paper presented before the American Institute of Electrical Engineers, at New York City, Nov. 12, 1909.

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The tunnel is lined with concrete throughout its length, and is in good condition. The roof is practically dry. The entire tunnel drips more or less from condensed steam just after the passage of a train, but is comparatively dry at other times. The temperature changes at the top of the tunnel are very rapid, varying from atmospheric temperature to several hundred degrees F., from the heat of the locomotive exhaust. For these reasons this tunnel is the limiting feature to the capacity of the Great Northern Ry. for hauling freight across the mountains.

Mallet compound engines are used on this division, one at the head of the train, and one pushing. The mountain section as a whole also fixes a limit to the capacity of the road, on account of the slow speed necessitated by heavy traffic; it is impossible for steam locomotives to haul heavy trains on the mountain at a greater speed than seven or eight miles per hour.

In general the plant comprises a hydroelectric generating station, operating under a head of 180 ft., having a capacity of approximately 5,000 KW. in generators at 6,600 volts and 25 cycles; a transmission system operating at 33,000 volts, delivering energy to a substation where it is transformed to 6,000 volts, at which pressure it is supplied to the overhead conductors and to the locomotive by way of an overhead trolley; on the locomotive the pressure is reduced by three-phase transformers to 500 volts for the supply of the four three-phase motors with which each locomotive is equipped.

This plant is designed for use over the entire mountain division, by extending the system of conductors and building additional stations; it was not designed for the operation of the tunnel alone, although even if the problem had been the handling of the traffic through this tunnel and its approaches only, the three-phase system would in all probability have been selected, on account of its greater simplicity and less cost. The choice of the system to be used was under consideration for more than a year; the three-phase system was finally decided on, plans were prepared, bids were obtained, and the contract for the four locomotives was let on June 22, 1907.

The original problem was to provide equipment to handle a train having a total weight of 2,000 tons, excluding the electric locomotives, over the mountain division from Leavenworth to Skykomish, a distance of 57 miles. The system was to be first tried out at the Cascade Tunnel.

The tractive effort required to accelerate a train having a total weight of 2,500 tons on a 2.2% grade, using 6 lbs. to the ton for train resistance and 10 lbs. to the ton for acceleration, making a total of 60 lbs. to the ton, is 150,000 lbs.; this would require four locomotives of a tractive effort of 37,500 lbs. each. The railway company's engineers limited the weight on a driving axle to 50,000 lbs.; therefore, four driving axles per locomotive are needed, giving a coefficient of adhesion of about 19%. This is a measure of the maximum power required. The locomotive was, therefore, designed to give a continuous tractive effort of approximately 25,000 lbs., and it was expected that four would be used with a train of maximum weight. But the locomotive as built greatly exceeds this specification.

Locomotive Design.

GENERAL FEATURES.—The principal data of the locomotive are as follows: Total weight 230,000 lbs. all on drivers; two trucks connected by a coupling, each truck having two driving axles; a three-phase induction motor connected by twin gears to each axle; gear-ratio, 4.26; diameter of driving wheels 60 ins. Synchronous speed of the motor is 375 r. p. m., giving a speed of 15.7 mi. per hr. at no load, dropping to 15 mi. per hr. for a load corresponding to the one-hour rating. The motors are wound for 500 volts and are completely enclosed and air-cooled; clearance between stator and rotor, ⅛-in. The trolley pressure is 6,000 volts; each locomotive has two three-phase transformers reducing the pressure from 6,000 to 500 volts, arranged with taps so that 625 volts may be used on the motor.

The distribution of the total weight of the locomotive is as shown in Table I.

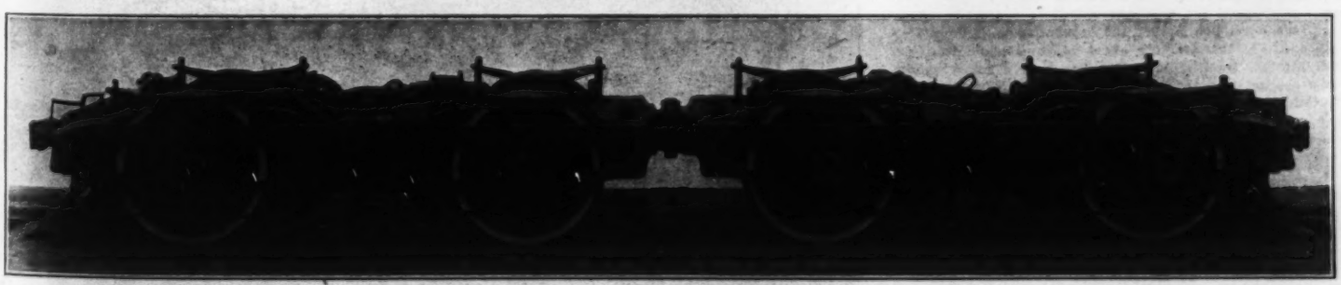


FIG. 2. ARTICULATED RUNNING GEAR OF THE GREAT NORTHERN THREE-PHASE ELECTRIC LOCOMOTIVE.

TABLE I.—WEIGHTS OF THE GREAT NORTHERN RY. THREE-PHASE LOCOMOTIVE.

2	Trucks	81,500 lb.
1	Cab	30,000 "
4	Motors	48,800 "
8	Gears and gear cases	11,000 "
2	Transformers	20,800 "
2	Air compressors	5,800 "
1	Blower	1,300 "
40	Rheostats	10,200 "
56	Contactors	3,200 "
	Miscellaneous	17,400 "
	Total	230,000 lb.
	Total weight per axle	57,500 "

The specification of the motor required an output of 250 HP. continuously for three hours with 75° C. temperature elevation, when supplied with not more than 2,000 cu. ft. of air per min. The test results of the

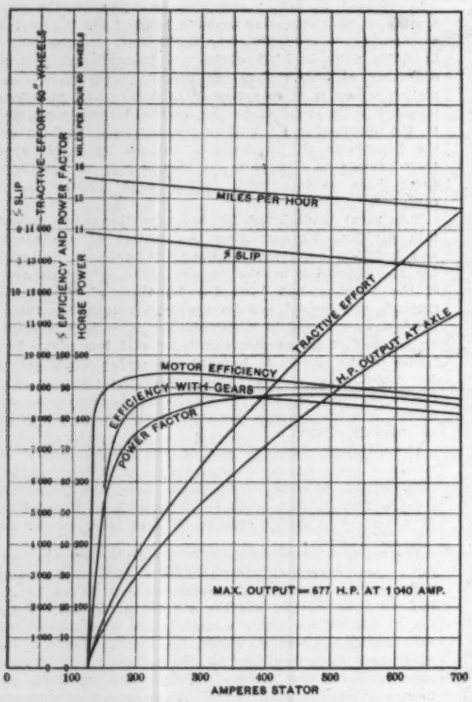


Fig. 3. Characteristic Performance Curves of Three-Phase Induction Motor, Great Northern Locomotive.

(475 HP., 25 cycles, 500 volts, gear ratio 4.26, 60-in. driver.)

motor show a continuous output of 375 HP. at 500 volts with 1,500 cu. ft. and 400 HP. at 625 volts, with the same air; the one-hour rating of the motor at 500 volts with 1,500 cu. ft. of air per min. is 475 HP.; the ratio of continuous output to the hour-rating with 1,500 cu. ft. of air is, therefore, 79%. The continuous output at 500 volts corresponds to a tractive effort of 9,350 lbs per motor and the one-hour output to a tractive effort of 11,900 lbs. per motor; the locomotive will, therefore, give 37,400 lbs. tractive effort in continuous duty, or 47,000 lbs. tractive effort for one hour. Fig 3 shows the characteristic curves of the motor, at 500 volts.

Calculations from the profile of the tunnel section give:

Westbound, Leavenworth-Cascade,	
Average up-grade	1.37%
Distance	32.4 mi.
Work per ton at the wheel rim	2.15 KW-hr.
Average power per ton at the wheel at 15 mi. per hr.	1.00 KW.
Eastbound, Skykomish-Cascade,	
Average up-grade	1.88%
Distance	24.8 mi.
Work per ton at wheel rim	2.16 KW-hr.
Average power for round trip per ton at wheel rim at 15 mi. per hr.	1.31 KW.
Average power per ton at wheel at 15 mi. per hr. for entire division	1.12 KW.
Maximum power per ton accelerating on 2.2% grade	1.8 KW.

These figures assume the train to be moving continuously and are based on 6 lbs. per ton train resistance, as are all calculations herein unless otherwise stated.

The average power of the locomotive necessary when pulling will then be 1.12 KW. per ton, and, therefore, each motor can carry 250 tons in continuous service on this mountain division, assuming there are no stops and no opportunity for cooling; or each locomotive could haul. (4 + 250 — 115) = 885 tons trailing load, if the power requirements were continuous. As there are necessarily stops, the rating as determined by heating is somewhat greater than this.

The locomotive has been tested to a maximum tractive effort of nearly 80,000 lbs., corresponding to a coefficient of adhesion of nearly 35%; with 60,000 lbs., or 26% each locomotive can accelerate the train of 885 tons trailing on a 2.2 grade, using 60 lbs. per ton as the total tractive effort; or, in other words, the train that a locomotive can haul, as determined by the average duty and safe heating limit, is just about equal to the train that it can accelerate on the maximum grade; that is, the average capacity of the locomotive and its maximum capacity are in the same proportion as the average duty and maximum duty. The design is well balanced.

Making some allowance for these figures for the sake of conservatism, the rating of the locomotive on this division can be put at 750 tons trailing load.

DRIVE EQUIPMENT.—The motors are suspended from the axles in the standard manner, except that they are geared at both ends of the armature shaft; this was made necessary by the low speed and high torque required, as it was not considered safe to use a single pair of gears. The gear had 81 teeth, the pinion 19 teeth, giving a gear ratio of 4.26. The gears are of specially hardened steel; in order to secure perfect alinement the two pinions on each shaft were cut simultaneously. At first it was the intention to use some form of spring connection between motor and driving wheel, but this was subsequently abandoned, as it seemed that there would be sufficient flexibility in the armature shaft to take out any small differences between the two sets of gears. As far as can be told at present, this assumption appears to be correct, for there has been no difficulty with the gears and no unequal wear. The gears run with little noise and the construction seems satisfactory.

The locomotive carries two three-phase air-blast transformers, having a nominal rating of 400 KW. each, transforming from 6,000 volts to 500 volts normally, or to 625 volts by the use of taps. The continuous capacity of the transformer is not as great as that of the motors, although it is fully up to the specifications, and it may be that the quantity of air to the transformer will have to be increased when the locomotives are put in continuous service.

Compressed air for the brakes is supplied by two 10-cu. ft. induction motor-driven compressors; the cooling air is supplied by a 9,400-cu. ft. motor-driven blower. The locomotive is equipped with a combined straight and automatic air-brake system.

CONTROL SYSTEM.—The control system of each motor is separate; the circuits branch from the transformer and are independent through the resistances.

FIG. 4. OVERHEAD CONSTRUCTION WITH BRACKETS. GREAT NORTHERN RY.

There are 14 contactors in each motor circuit, 56 in all. The pilot control is in duplicate, one switch at each end of the locomotive. At first I intended to have two running speeds by changing the number of motor poles, but this led to many complications; every effort was made to keep the equipment as simple as possible, and I finally decided to use resistance control in the rotor of the motors and to have a single-speed unit.

Iron grid resistances are provided for each motor. There are thirteen steps in the control, but in order to reduce the number of contactors to the lowest possible point an unsymmetrical system is used. A change is made in the resistance of one phase only, in passing from step to step. On each step of the control the torque is the average of the three values of the torque of the separate circuits. The principal advantage of this is that 56 contactors do the work that would otherwise require 128, thus effecting a great gain in the simplicity of the control apparatus.

Experience with the locomotive in service indicates that the initial torque, which is approximately 20,000 lbs., is somewhat high, and I am now having the control changed so that on the first step two motors only will be thrown in circuit, and on the second step all four motors.

RUNNING GEAR.—The locomotive is an articulated type, having four driving wheels on each half of the running gear and is without guiding wheels. The hinged sections are so rigidly connected that they tend to support each other vertically and guide each other in taking the curves, although the hinges are designed to offer minimum resistance to lateral flexure. The truck section on the one end is side equalized, but the section on the other end is carried on a three-point suspension.

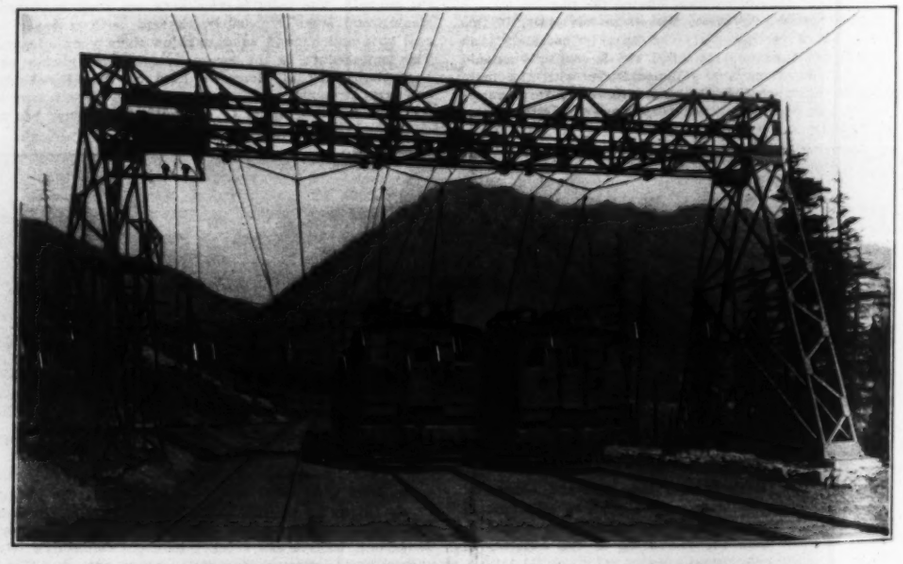


FIG. 5. ANCHOR BRIDGES, CASCADE TUNNEL YARDS; GREAT NORTHERN RY.

The framing of the running gear is of substantial steel castings annealed and held together by body-bound taper bolts in reamed holes. Side-frames are castings of truss pattern; end-frames and bolsters are steel castings of box-girder type; the end-frames and all parts are designed for buffing stresses of 500,000 lbs. Bolsters are hollow castings and form part of the air reservoir for the motor ventilation; the air being supplied through a hollow centre pin. The 60-in. wheels have removable steel tires 3.5 in. thick. The wheel-centres are steel castings. The gears are shrunk on an extension of the wheel-hub, thus eliminating the torsional stresses from the locomotive-axles. The motors are connected through gears at both ends.

The cab is carried on the trucks through centre pins on each bolster, the centre pin on one end having a slight longitudinal motion to allow for variation in the distances between truck centre-pins in taking curves. The cab extends the entire length of the platform and is made of No. 10 steel plates which carry a monitor that supports the trolley base and has a ventilated opening running through the centre and perforated side plates to permit the escape of air from the interior of the cab. The greater part of the control apparatus, the rheostats, the transformers, contactors, etc., are placed in a separate compartment 60 ins. wide and 22 ft. long, enclosed by steel partitions extending directly up to the monitor roof. This leaves two open operating spaces at the ends of the locomotive, connected together by two side aisles 30 ins. in width. The centre compartment is divided into three parts by steel-plate partitions, the middle part containing the high-tension apparatus, including the switchboard. The end parts are duplicates, each containing one transformer and the contactors for two of the motors. The rheostats are placed in the monitor at the top of the cab. The air for ventilation, after passing through the transformers, cools the rheostats and then escapes to the atmosphere. Placing these rheostats at the top of the cab has also the advantage of raising the center of gravity of the locomotive, which is nearly 60 ins. above the rail head, higher than is usual with electric locomotives.

In the yards at both ends of the tunnel, the main track and two side tracks are electrified, together with the necessary crossovers, etc. The total length of the track equipped, including the tunnel, is about six miles. The length of the several parts of the overhead structure is as follows:

Sub-station to east portal of tunnel...	200 ft.
East portal to west portal	13,900 ft.
West portal to end of electrified track....	6,960 ft.
Total, sub-station to rear electric locomotive	21,060 ft.,

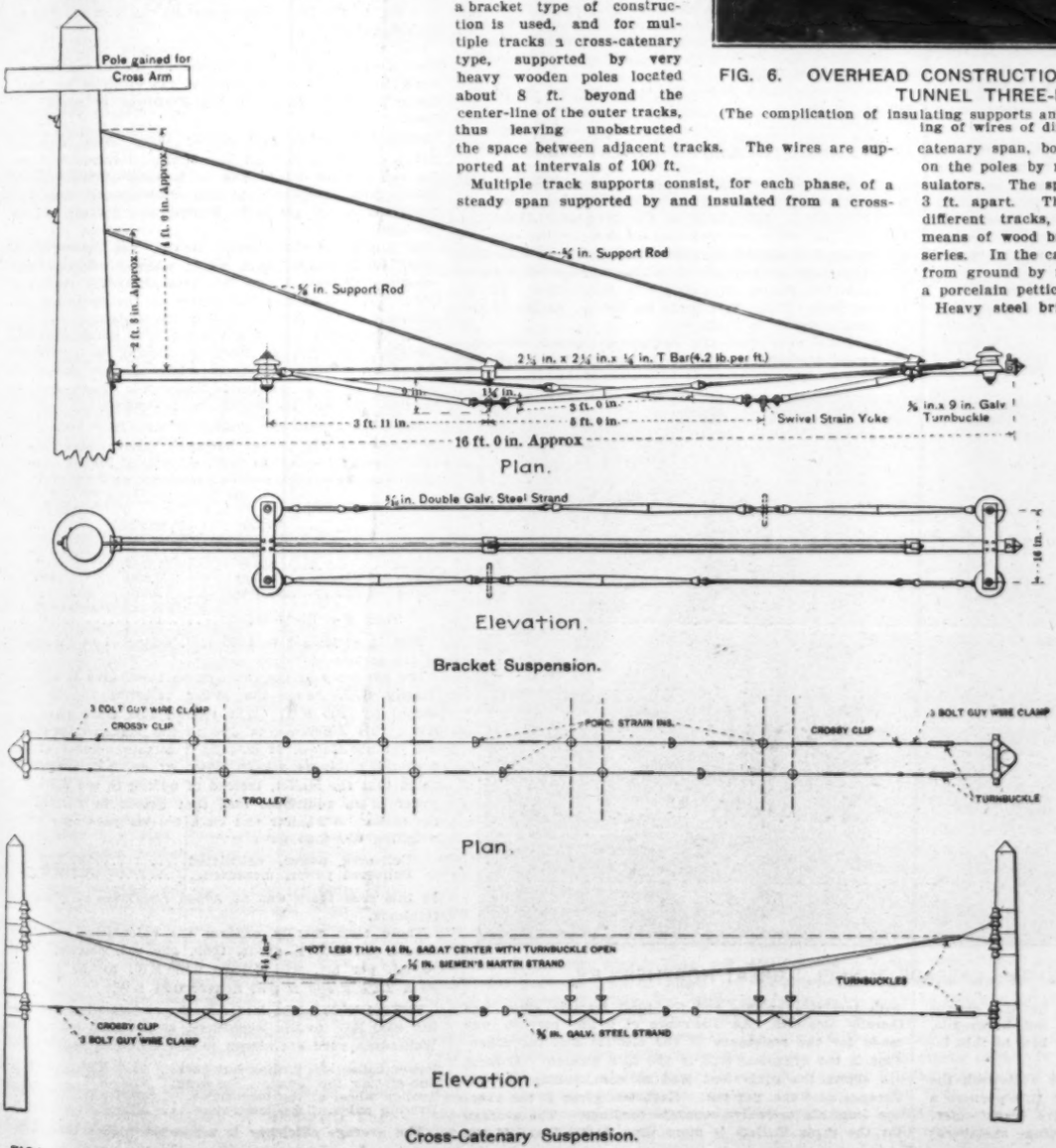
or, practically, 4 miles.

OVERHEAD CONSTRUCTION IN YARDS.—Figs. 4, 6, 7 and 8 show the general type of bracket and cross-catenary construction used in the yards. The wires are 24 ft. above top of rail and 5 ft. apart; for single tracks a bracket type of construction is used, and for multiple tracks a cross-catenary type, supported by very heavy wooden poles located about 8 ft. beyond the center-line of the outer tracks, thus leaving unobstructed the space between adjacent tracks. The wires are supported at intervals of 100 ft.

Multiple track supports consist, for each phase, of a steady span supported by and insulated from a cross-catenary span, both spans being secured to cross-arms on the poles by means of porcelain petticoat strain insulators. The spans for the two respective phases are 3 ft. apart. The wires of the same phase, for the different tracks, are insulated from each other by means of wood breaks and porcelain link insulators, in series. In the case of brackets, each phase is insulated from ground by means of a wood break in series with a porcelain petticoat strain insulator.

FIG. 6. OVERHEAD CONSTRUCTION AT SWITCH POINTS. CASCADE TUNNEL THREE-PHASE LINE.

(The complication of insulating supports and frogs is made necessary by the crossing of wires of different phase.)



FIGS 7 AND 8. CROSS-CATENARY AND BRACKET SUSPENSION OF OVERHEAD WORK. CASCADE TUNNEL LINE.

Heavy steel bridges, Fig. 5, forming anchorages for the trolley wires are located in both yards at intervals of 1,000 ft. Lightning protection, though thunder storms are rare, is afforded by arresters connected to the wires at the ends of the tunnel and yards.

Where wires of opposite phases cross at turn-outs, they are insulated from each other by section insulators made of wood and about 5 ft. in length; four insulators are used, each connected at one end to a special 8° crossing pan and at the other end to one of the four wires converging toward the crossing. Except for one track, whose wires are cut straight through the crossing pans without section insulators, it is necessary to switch the controller to the off position when the trolley wheel passes under the insulators; methods of avoiding this have been considered and are being tried out.

Both rails in the tunnel and one rail in the yards are bonded, with cross-bonding at frequent intervals. A single 0000 exposed bond is used at each joint, having a length of 36 ins. in the tunnel, and 36 and 50 ins. in the yards.

In my opinion the use of double insulation everywhere is the reason for the almost total freedom from troubles of any kind, origipating on the overhead structures. The only troubles experienced, up to the present, have been at the section breaks and turnouts, and have been caused by the trolley wheel leaving the wire. There has been no failure of the wires at any point of the overhead structure nor any breakdown of insulation.

OVERHEAD CONSTRUCTION IN TUNNEL.—This construction is shown in Figs. 9 and 10. Fig. 10, however, does not show the swiveled connection of the stud to the clamp holding the trolley wire at the lower

end. The necessity for adding this swivel connection was shown by the breakage of several studs. Each wire is supported every 50 ft. Anchors and side-braces for the wires in the tunnel are located at intervals of 3,000 ft.

Practically all metal work in the tunnel supports is copper or bronze, but experience has shown that galvanized iron, soon becoming protected by a slight coating of soot, would have been satisfactory. The in-

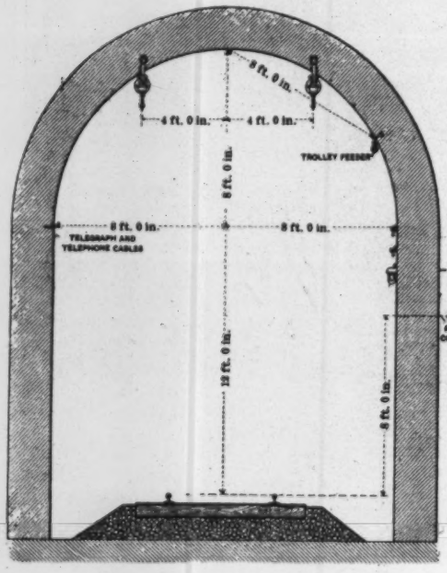


Fig. 9. Cross Section of Cascade Tunnel.

(Showing location of trolley wires, feeders, cables, etc.)

sulators, when first put in service, were covered by a very thick coating of wet soot, but, even under these conditions, it was found possible gradually to bring the voltage up to normal without breakdown. Volumes of smoke and steam issuing from steam locomotives caused only a slight surface leakage, and one rough cleaning sufficed to put the insulators in reliable working condition.

Necessity of spacing the wires 8 ft. apart in the tunnel complicated the construction somewhat and was one of the principal reasons leading to the use of a trolley wheel in place of a bow collector. It has, however, caused no material inconvenience and is satisfactory as long as the trolley wheels are in use, but if a change is made to a bow collector, which is not impossible, there may be difficulty in adapting the bow to this location of the wires.

It is intended ultimately to clean and whitewash the tunnel and light it electrically, and for this purpose a lighting system has been installed. Five transformers of 4-KW. capacity each are placed in refuge chambers; incandescent lights are spaced 50 ft. apart and are connected five in series of a 500-volt system. Several plans were worked out for this lighting system, but taking into account maintenance costs, it seemed best to use a standard 110-volt carbon-filament lamp. The telegraph wires, ten in number, run through the tunnel in a cable; this service was thrown entirely out of commission when the electric locomotive began running. There is no interference with the telegraph wires due to the transmission lines paralleling them for 30 miles; the entire interference seems to originate in the tunnel. In order to eliminate this interference, a neutralizing transformer has been installed and adjustments are now in progress. There has been little difficulty in making the ordinary single-wire telegraph service satisfactory, but considerable difficulty has been experienced in getting the quadruplex to work satisfactorily; this matter is still unfinished.

Operation of the System.

The electric service was started on July 10, although one or two trains had been handled previously. From that time to August 11, practically the entire eastbound service of the company was handled by electric locomotives.

During this period of 33 days there have been 212 train movements of which 82 were freight, 98 passenger, and 32 special. In each case the steam locomotive was hauled through with the trains. The tonnage handled was as follows:

Freight tonnage	171,000	tons
Passenger tonnage	88,500	"
Special tonnage	15,500	"
Total	275,000	tons

This is an average of 8,350 tons per day, all eastbound.

The average freight train weight has been as follows:

Cars	1480	tons
One Mallet locomotive	250	"
Three electric locomotives	345	"
Total train weight	2075	"

The maximum weight of cars was 1600 tons; the minimum 1200 tons.

The representative passenger train handled is made up as follows:

Coaches	426	tons
One steam locomotive	250	"
Two electric locomotives	230	"
Total train weight	906	tons

The maximum was about 125 tons greater.

FRICTIONAL RESISTANCE OF STEAM LOCOMOTIVES.—The power required to haul these trains seemed greater than it should be; investigation showed that the difference was accounted for by the unexpectedly high frictional resistance of the steam locomotives, as a trailing load. Tests were made on several engines with the results shown in Table II.

The tests were made by towing an engine through the tunnel behind an electric; the electric was fitted up with test instruments and the total tractive effort was thereby obtained. An allowance of 6 lbs. per ton was made for the resistance of the electric and the difference is the draw-bar pull in the fifth column. Column six shows the equivalent load in cars, taking car resistance as 6 lbs. per ton. Each test given is the average from six to twelve separate readings. The average for the three Mallets is more than 20,000 lbs. If the grade resistance be deducted from the total pull, and the difference be lumped as "lbs. per ton" for the locomotive and tender, columns seven and eight result.

The average for the three Mallets is 47.0 lbs. per ton for the frictional resistance on a straight level track.

The figure for the electric was obtained from tests made at Schenectady by towing it by a motor car on straight level track; this test was made at Schenectady. Included in it is the resistance of gears and bearings of motors.

Using 20,000 lbs. as the pull required for a Mallet on the 1.7% grade (the approximate average from Table II.), the total tractive effort for the average freight train, is:

Cars	1480 tons	× 40 =	59,200 lbs.
One Mallet	250 tons	× 80 =	20,000 lbs.
Three Electrics	345 tons	× 40 =	13,800 lbs.
Total tractive effort			93,000 lbs.

This is equal to 31,000 lbs. for each electric locomotive.

On account of the very high frictional resistance of the Mallet engine as a towing load, this representative train is equivalent to 1980 tons, excluding the three elec-

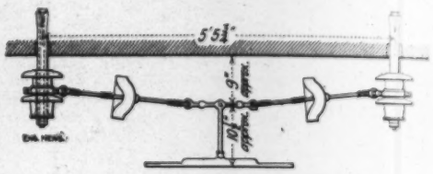


Fig. 10. Elevation of Tunnel Suspension Scheme.

tric locomotives, or a total of 2,325 tons, on the 1.7% grade. This is on the assumption that the draw-bar pull required for the Mallet is replaced by freight cars at 6 lbs. to the ton; this represents the average freight train handled.

The tractive effort for the passenger trains varies from 40,000 to 50,000 lbs. depending on the number of steam locomotives taken through; two electrics are ordinarily used, although one would answer in nearly all cases.

DELAYS.—During this period there have been no delays due to failure of the electric locomotives, and but two trifling delays due to failures of the electric plant, both chargeable to the transmission line and both caused by accidents beyond the control of the operating force.

On August 11 the electric service was discontinued, owing to failure of both water wheels. Service was resumed on Sept. 9 and has been continued regularly since. The plant was taken over by the operating department of the railroad late in September.

The westbound service was not at first handled by the electrics regularly, as there is nothing in particular gained by braking the trains electrically on this short stretch, but now westbound passenger trains are so handled, for the benefit of the passengers.

REGENERATING.—A number of tests have been made to determine the power returned when regenerating. The following is typical, with a train of Mallet engine, 1,550 tons car weight, and two electrics, on 1.7% grade:

	Grade Resistance lb.	Frictional Resistance lb.	Remainder for Deceleration lb.
Mallet	8,500	11,500	- 3,000
1550 tons cars	52,500	9,300	+43,200
Three electrics	11,700	2,070	9,630
Total for Deceleration			49,830

This is equivalent to 1495 KW. delivered to the gears of the motors at 15 mi. per hr.

The efficiency of the three-phase locomotive is approximately 80%, hence the power returned to the line should be 1200 KW. The test of this train gave 950 KW.; this difference is due to the standard practice, not yet abandoned, of keeping a certain number of car pressure retainers set on down grade. It should be noted that the Mallet, instead of adding to the delivered power is an additional load that has to be carried by the train. A similar test on a ten-car passenger train weighing 950 tons gave

Delivered power, calculated	590 KW.
Delivered power, measured	597 KW.

In this case there was no added resistance of pressure retainers.

These tests merely confirm the calculation, as they should. On a 1.7% grade, then, one ton, descending at 15 mi. per hr., will deliver 0.67 KW. to the system; on a 2.2% grade it will deliver 0.91 KW.

EFFICIENCY.—The losses in the system when delivering 4000 KW. to the locomotive, at the west end of the Wellington yard are shown in the following tabulation:

Power house low tension bus-bars	4740 KW.	100 %
Sub-station low tension bus-bars	4250 KW.	89.8%
Trolley wheel of the locomotive	4000 KW.	84.3%
Driving axles of the locomotive	3320 KW.	70 %

The average efficiency is somewhat higher than 70%.

FIG. 11. ENTRANCE TO THE CASCADE TUNNEL. GREAT NORTHERN RY.

TABLE II.—FRICTIONAL RESISTANCE OF STEAM LOCOMOTIVES.

Test No.	Engine classification	Total Tons with tender	Tons on drivers	Total resistance on 1.7% grade lbs.	Equivalent Tons of freight cars	Frictional resistance of locomotive Total lbs.	lbs. per ton
1	Mallet No. 1904. 2-6-6-2	250	158	19,340	482	10,840	43.0
2	" No. 1911. 2-6-6-2	250	158	17,500	432	9,000	36.0
3	" No. 1905. 2-6-6-2	250	158	24,200	602	15,700	63.0
4	Consolidation 2-8-0	159	90	10,080	255	5,480	34.5
5	Pacific 4-6-0	188	70	10,270	257	3,870	20.7
			Electric			1,500	13.0

HANDLING TRAINS.—The maximum duty was imposed upon this equipment from the outset. On account of very poor regulation of water wheels, steam has been used in one of the Mallet engines in starting the freight trains in the Wellington yard; an attempt has been made to use just sufficient steam to enable the Mallet engine to turn itself over. Steam is shut off at the portal of the tunnel; in addition to this, in order to provide smoother starting a slight air pressure has been maintained on the locomotive at starting, which is gradually reduced.

On several occasions trains have broken in two, due to a trolley wheel on the rear locomotive leaving the wire and thus cutting off part or all of the power supply to the rear locomotives. This throws a greatly increased draw-bar pull on the front locomotive, and the consequence is that the train is jerked apart. This happened in the early stages of the work, and was due to the fact that the turn-outs were not in the best order, and also that the engineers had not sufficient experience in handling trains. Another means taken to avoid the broken draw-bars was to use the rear Mallet engine to assist the train over the trolley crossings in the Wellington yard, but this was only a temporary measure and has been discontinued.

ECONOMY OF MALLETS.—It is interesting to compare the performance of a Mallet compound locomotive under the same operating conditions as this system. The data for this are given by Mr. G. H. Emerson, superintendent of locomotive power of the Great Northern Railway Co. in a discussion before the American Society of Mechanical Engineers on locomotives of this type;* as an excellent performance he gives these data:

Recent performance shows that, on a round trip over this division, the L-1 engines handled 1,600 tons with a total of 43 5/6 tons of coal, or equivalent to 25.13 lbs. of coal per 100 ton-mile.

The division referred to is from Leavenworth to Everett, 108.7 miles. The work done per ton for a round trip over this run is readily calculated; from the profile I find,

Total rise, westbound	2,212 ft.
Total rise eastbound	3,440 ft.
	5,652 ft.

and $5{,}652 \times 2{,}000/2.65 \times 10^3 = 4.26$ KW.-hr., at the rail. This is the work done per ton in lifting the train. The work done against train resistance, assuming resistance to be 6 lbs. to the ton, for 108.7 miles, is 1.3 KW.-hr. The total work done in round trip per ton 5.56 KW.-hr. There is a negligible addition to this for starting the train.

The average train weight is:

Cars	1,600 tons
One engine, 109 miles Second engine, 58 miles Equivalent engine weight	380 tons
Total	1,980 tons

The coal used by the Mallet was 43 5/6 tons, equal to 87,660 lbs.

Coal per ton	44.3 lbs.
Coal per equivalent KW.-hr.	8.0 lbs.

A modern steam station can deliver one KW.-hr. for 3 lbs. of coal, at the bus-bar, which, with an efficiency of 70% to the rail, gives a consumption of 4.28 lbs. per KW.-hr. at the rail. The Mallet compound requires nearly twice as much coal per KW.-hr. at the rail as would be used in a modern steam station in the place of the hydroelectric station at Leavenworth.

Advantages and Disadvantages of Three-Phase System.

This plant has demonstrated, in my opinion, that the three-phase induction motor has certain very marked advantages over any other form of motor for heavy traction on mountain grades; these advantages may be stated somewhat approximately.

(1) Maximum electrical and mechanical simplicity. The motors will stand any amount of abuse and rough use.

(2) Greater continuous output within a given space than can be obtained from any other form of motor. The losses can be kept lower in a three-phase motor than in any other type and the electrical efficiency of the motor is high for a wide range of load.

(3) Uniform torque.—I believe that a three-phase motor will work to a 3 or 4% greater coefficient of adhesion than a single-phase motor at 15 cycles.

(4) The possibility of using 25 cycles.—This leads to a less cost and a better performance of power station apparatus; moreover, it is standard and the power supply can readily be used for other purposes.

(5) Constant speed.—This is ordinarily stated as a disadvantage of the three-phase motor; but in my opinion it is a distinct advantage in mountain service, particularly the limitation of the speed on down grades. It has also the advantage, on up grades, that meeting points can be arranged with greater definiteness. There is a general notion that the impossibility of making up lost time with the three-phase motor will be a decided drawback to its use. This would be true if there were the same liability to lose time with three-phase motors; but when a train can be counted on to make a definite speed, without regard to conditions of tracks or of its load there is less liability to lose time. Although I am not prepared to state that a three-phase motor is suitable for cases where the profile is very variable, yet it is by no means certain that it would not work out well; the question is merely one of making a given schedule between two points with greatest regularity.

(6) Regeneration on down grades.—This matter has been discussed since the earliest days of electric traction, but, as far as I know, has not been, up to the present, put into practice. It is most perfectly attained by three-phase motors, there being no complications involved. No doubt, the saving in power-house capacity will not be as great as indicated by theory, owing to the various emergencies that must be provided for, nevertheless there will be a material saving. A 2,500-ton train on the average down grade of 1.5% will deliver about 1,400 KW. to the system. The equivalent power-house capacity would cost at least $200,000; hence if only 20% of this can be utilized the saving will equal the cost of one locomotive.

(7) Excessive short-circuit current is impossible and consequently destructive torque on the gears and driving rigging is eliminated. There will be no necessity for the complication of a friction connection between the armature and driving wheels, as in the design of recent large direct-current electric locomotives.

(8) Impossibility of excessive speeds.—Even when the wheel slips the speed remains constant. Therefore, the maximum stresses put on the motor are less and are more accurately known than with any other form of motor.

On the other hand, the principal disadvantages of three-phase motor, for traction use, are commonly stated to be:

(1) The constant speed.—This is rather an advantage for this class of service.

(2) Constant power.—The motor is a constant-power motor and therefore requires the same power at starting and while accelerating as at full speed. This is not a matter of any particular consequence in a service where the stops are very few and consequently the proportion of total time spent in acceleration is small, and where the additional power required to accelerate the train is a small percentage of the power used by the train at full speed. In this particular case on the 2.2% grade, when accelerating at the rate of 10 lbs. to the ton, the power required during acceleration is only 20% greater than that required at full speed; this is not a serious matter.

(3) Small mechanical clearance.—In this particular motor the clearance is ⅛-in., which is ample for all practical purposes.

(4) Inequality of load on several motors of a locomotive due to differences in diameter of driving wheels.—To meet this an adjustable resistance is included in the rotor of each motor, the motors are then balanced up and no further attention is required as long as the wear on the driving wheels is approximately the same. If, at any time, the load becomes badly unbalanced it is a simple matter to readjust the resistances.

(5) Low power-factor of the system.—This does not seem to be borne out by practice. The power-factor, as shown by the switchboard instruments in the power-house, is 85%. This is a good result and is much higher than the power-factor of a well-known single-phase system that I recently had occasion to visit.

(6) Two overhead wires.—There is no doubt that two wires will cause more trouble than one, and in case of complicated yard structure it might not be practicable to use two overhead wires; but where the problem is that of a single track with an occasional turn-out or crossing there is, practically speaking, no more difficulty in maintaining two wires than one.

In brief, in service of this character the three-phase motor has marked advantages in capacity, reliability, simplicity, and general trustworthiness, when compared with any other motor.

*Transactions, American Society of Mechanical Engineers, Vol. 30, page 1081.

The Three-Hinged Reinforced-Concrete Arch Across the Vermillion River, Wakeman O.

In the 1909 Proceedings of the Ohio Engineering Society there is a description by Mr. Wilbur J. Watson, M. Am. Soc. C. E., Cleveland, Ohio, of an economical long span highway bridge that has recently been built to take the place of an old wrought-iron truss bridge across the Vermillion River at Wakeman, Ohio.

From the original paper we have abstracted the following account of the bridge design:

The bridge consists of a single 3-hinged reinforced-concrete arch of 145 ft. span c. to c. of lower hinges, and 32 ft. 6 ins. rise c. to c. of lower and upper hinges, with cantilevers at each end of 37 ft. 3 ins. length from the center of the lower hinges to the ends of the cantilevers giving a total length of 219 ft. 6 ins., between abutments. The width of the roadway is 18 ft. between curbs and the total width of the bridge is 21 ft., the arches being designed for the addition of sidewalks at any time in the future, provision for which has been actually made by embedding bolts in the concrete on the south side of the bridge.

The arch consists of two parallel ribs. The reinforced-concrete floor which contitutes the wearing surface of the roadway is carried by longitudinal and cross beams which in turn are supported by spandrel posts carrying their loads to the arch rings.

For this particular structure the thrust at the crown for a 3-hinged arch was 501,000 lbs., while the thrust at the crown for a fixed arch was 520,000 lbs. The principal economy, however, of the 3-hinged over the hingeless arch for an arch of this type and dimensions is due to the decreased bending moments in the arch rings caused by the cantilevers. As a matter of fact, the sum of the total bending moments at each panel point in the 3-hinged arch amounted to only about 25% of the sum of the total bending moments in the hingeless arch. The cost of the hinges necessary for the 3-hinged arch was very considerably less than the cost of the additional steel reinforcing in the arch ring required to take care of the additional bending moments in the hingeless arch. This is a matter that the writer went into with considerable detail as he confesses that he was rather surprised himself at the result and could hardly believe it until he had carefully checked over the figures. The result certainly constituted a very decided argument in favor of the 3-hinged arch. The cast steel hinges are entirely encased in concrete, this having been done after the centers were struck, a ¼-in. plate of sheet lead having been placed at the center of each hinge to allow the necessary motion of the arch rib under live load and temperature stresses. In this way all possibility of corrosion of steel hinges has been avoided.

The cantilever ends decrease the dead load thrust on the center hinges about one quarter, decrease considerably the angle which the resultant thrust on the lower hinge makes with the vertical, thus decreasing the size of abutment required, and eliminate entirely the necessity of providing sliding expansion joints. The elimination of the sliding expansion joint is a very desirable feature in a bridge of this character, as such joints are difficult to construct and are very apt to give trouble. There is no connection whatever between the ends of the cantilevers and the abutments, an open vertical joint being provided at these points. The vertical motion of these joints is a negligible quantity in a structure of this kind.

The unit stress allowed on steel bars was 20,000 lbs. per sq. in. in the roadway slabs where high carbon bars were used and the maximum stress was caused by the concentrated live load, and 16,000 lbs. in all other places. The corresponding stresses in compression were 12,000 and 10,000. The maximum allowed compression in concrete was 750 lbs. per sq. in. under cross bending stresses when computed by the straight line method (which corresponds to about 640 lbs. actual unit stress) and 500 lbs. per sq. in. under direct compression. No allowance was made for concrete in tension. The maximum allowable shearing stress on concrete was 50 lbs. per sq. in.

All concrete used in the arch rings, floor and arch details was composed of one part cement, two parts sand and four parts stone (¼ to 1½ ins.), while the concrete for the skewbacks was composed of one part cement, three parts sand and six parts stone.

Some changes were made in the work during construction consisting of additional grading, additional masonry in the west abutment, etc., bringing the final estimate up to the sum of $16,870.45, which is about $800 less than the engineer's estimate.

The contract was awarded to the Schillinger Bros. of Columbus, Ohio, and Chicago, Ill. The bridge was built under the direction of the authorities of Huron County, Mr. John Laylin, County Engineer and Mr. Herrick, Assistant County Engineer, with the writer as consulting engineer.

The Accident to the Poe Lock Gate at the St. Mary's Falls Canal, Sault Ste. Marie.

On Nov. 10, 1909, at 7.45 a. m., the southerly of the two upper service gates of the Poe lock at the St. Mary's Falls Canal, on the American side at Sault Ste. Marie, was rammed by the steamer "Isaac L. Elwood" and so seriously injured as to put the lock out of commission for a week. Fortunately at the time of the collision the lower gates were closed so that there was no damage from rushing water such as occurred in the accident to the Canadian lock on the other side of the river on June 9, 1909 (Eng. News, June 17, 1909, p. 672). Immediately, work was started toward replacing the injured gate with the similarly designed upper guard gate and it is expected that the lock can be put into service within one week from the time of the accident. During the interim the boats on the lake were locked through the small Weitzel lock on the American and the Canadian lock on the Canadian side.

The Poe lock at the "Soo" is 800 ft. long between upper and lower service gates and is 100 ft. wide. It is provided with two sets of gates at each end, one set for guard gates and the other for service. At the upper end the service and guard gates are practically duplicates, so as to be interchangeable in case of emergency. Each of the gates is of the double-skin arched type, with an air chamber in the bottom and a water chamber above.

On the morning of the accident one small steamer, with two barges in tow, and one large steamer were in the lock bound down, with the water at the upper level in the lock. When the barges moved into the lock the "Elwood," which had been lying astern of the barges, moved up to lie at the usual waiting point, a few hundred feet above the lock. The south leaf of the upper gate was closed, or nearly so, and the north leaf just started to close, when it was seen that the "Elwood" was not going to stop at the usual point. The north gate was then opened again and locked to the wall, but there was not time to open the south gate, and it was swinging a few feet from the sill when the bow of the "Elwood" struck it near the center. The gate apparently moved over rapidly to the sill, followed by the steamer. The boat's bow appeared to ride up on the gate as it would on a heavy cake of ice, and then moved back away from it. There are two bad dents in the up-stream face of the gate (Fig. 3), the larger one having been made apparently after the gate had "brought up" against the sill.

The press reports state that the master of the steamer, when interviewed, said he had twice signaled the engineer to back the wheel, but that his boat kept gaining speed ahead. That the engines were not reversed until the gate was struck seems to be established by several eye-witnesses, who estimate that the boat was traveling 4 or 5 miles an hour when she hit the gate. It is understood that two cables were out on mooring posts, but these failed to stop the boat. From such information as can be obtained at present, it appears that this accident was due to the engineer of the boat not knowing in what direction his engine was working, and, although the result of the official investigation into the cause of the accident to the Canadian lock earlier in the season has not been made public, it is generally believed that it was from the same cause.

After the accident, the upper and lower guard gates were closed and the lock pumped out far enough to permit an examination of the sill against which the damaged gate struck. This did not appear to have suffered any serious injury. Examination did show, however, that the water chamber and air chamber of the damaged gate were both leaking badly. It was thought undesirable to attempt any permanent repair on the gate, and preparations were made to replace it by the guard gate above. In order to permit the safe lifting of the damaged gate it was patched and calked sufficiently tight to keep the water chamber at the top empty and to make it possible to regulate the amount of water in the lower chamber.

When these repairs were completed the lock was allowed to fill to the lower level, and the pontoon, loaned by the officials of the Canadian Canal, was brought into the lock. The lower service gates were then closed and the lock allowed to fill nearly to the upper level. Thus the water level could be held at a desired point while attaching to the gate the cables of the pontoon. When this was accomplished the anchorage pin was removed and the gate raised sufficiently by the pontoon to float it out. The lock was then allowed to fill completely, the

Fig. 1. View of Gate Hauled Back in Recess.

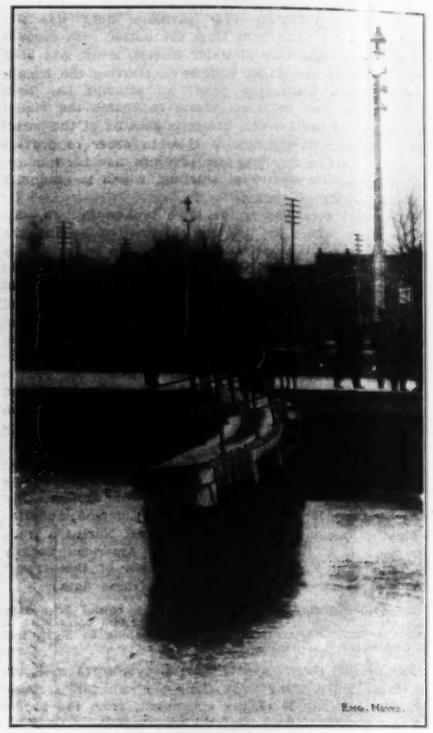


Fig. 2. View of Gate in Place Against Miter-Sill.

THE RESULT OF A COLLISION WITH A GATE OF THE POE LOCK, SALT STE MARIE, MICH.

FIG. 3. VIEW OF BACK OF POE LOCK GATE SHOWING POINT OF COLLISION.

upper guard gates opened and the pontoon, with the gate, floated to a point where the latter would be out of the way. By a similar method the guard gate was moved down to take the place of the service gate. At the time of going to press the Superintendent of the canal informed us that the change would be made by Nov. 17.

Notes from Engineering Schools.

UNIVERSITY OF MICHIGAN.—Two new courses have been established by the Regents of the University. One of these courses is in "conservation engineering" and will extend over a period of six years. It will be given jointly by the literary, law and engineering departments.

The students in "conservation engineering," on the completion of 140 hours of work, covering four years and a summer session, will be granted the degree of Bachelor of Science in Engineering, and upon the completion of 175 hours of work they will be granted the degree of Master of Science in Engineering. Upon the completion of 210 hours of work, requiring six years and summer session, the student in the course will receive the degree of Master of Conservation Engineering.

This is probably the first course of the kind ever offered by any university, and its purpose is to train men for the work of conserving, developing and utilizing the vast sources of mineral, animal and vegetable wealth, and the now largely wasted energy of water power; for the improvement of agriculture, and for the amelioration of sanitary conditions.

The new branches are to be taught as the course is rather a combination of courses in the engineering, law and arts departments. The recommended program is as follows:

Cultural subjects and language, 45 hours; law and political economy, 15 hours; mathematics and astronomy, 27 hours; physics and chemistry, 18 hours; geology and mineralogy, 15 hours; biology, botany, zoology and forestry, 20 hours; drawing and surveying, 21 hours; civil engineering, 16 hours; mechanical engineering, 11 hours; electrical engineering, 8 hours; chemical engineering, 6 hours; elective, 8 hours; total, 210 hours.

This second new course is in landscape design. The bachelor's degree is given after four years and a master's in five.

A FIRE IN A GOLD MINE in West Australia is reported Nov. 10 as having already done damage estimated at $1,500,000. The burning mine is known as the Great Boulder gold mine.

A COAL MINE EXPLOSION in the Auchincloss colliery of the Delaware, Lackawanna & Western Coal Co. at Nanticoke, Pa., Nov. 9, caused the death of nine miners. The men were not killed by the explosion directly but by the fire which followed.

AN EXPLOSION OF GASOLINE in a home at Warroad, Minn., Nov. 9, caused the death of six persons. One of the victims was pouring what was thought to be kerosene oil on a fire in a stove when an explosion occurred, throwing blazing oil in all directions. It was found that a clerk at the store where the oil was procured had poured gasoline into the kerosene tank.

A MOST DISASTROUS MINE ACCIDENT took place Nov. 13 in the mine of the St. Paul Coal Co. at Cherry, Ill. An explosion of dust or gas was followed by an uncontrollable fire which spread rapidly through the workings and cut off the escape of all but about 25 of the miners. About 300 men were left in the mine and presumably have perished. Thirteen volunteers descended the shaft in the cage immediately after the explosion in the hope of rescuing those near the shaft. When the cage was hauled up after a considerable wait for signals, it was found to contain only the members of the rescue party, all dead from suffocation. After ineffectual efforts to check the fire with water and after the destruction of the fan, the mouth of the shaft was sealed up in the hope of smothering the fire. It was reopened the following morning, Nov. 14, and men equipped with oxygen helmets were lowered into the mine, but were unable to find any bodies, dead or alive. It was believed that the miners had been driven to the more remote parts of the mine by the fire. No flames were seen and the temperature was not excessive but the atmosphere was unbreathable. The shaft was sealed shut again on the night of Nov. 14 but was reopened on Nov. 15 and fans were started in the hope of clearing the mine of gas. The fans only served to again the mouth of the shaft. On Nov. 16, 200,000 gals. rekindle the fire and it was soon necessary to seal of water, brought in tank cars, was poured into the mine but without apparent effect. The fire started in a pile of hay in the mule stable.

A CAVE-IN IN A RAILWAY CUT at Salem Creek, near Winston-Salem, N. C., Nov. 16, killed six workmen. The accident occurred on the new extension of the Norfolk & Western Ry.

A COLLISION AT SEA between the barkentine "John S. Bennett" and the four-masted schooner "Herrill C. Hart" Nov. 8, three miles off Block Island, R. I., resulted in the death of 13 men. Both vessels sank.

A collision between the French steamer "La Seyne" and the steamer "Onda" of the British-India line Nov. 14 caused the French vessel to sink within two minutes. About 100 persons from the sunken steamer were drowned and 61 were rescued. The accident occurred in the Rheo Straits, India, at about four o'clock in the morning.

A POWDER MILL EXPLOSION Nov. 11 wrecked a press mill and a grinding mill of the E. I. Du Pont de Nemours Powder Co., near Wilmington, Del. Three persons were killed and seven injured. In addition to the two buildings wrecked by the explosion, other small buildings belonging to the powder company and a number of dwellings were more or less damaged.

A RUNAWAY CAR on the British Columbia Electric Ry. wrecked a pasenger car near Vancouver, B. C., Nov. 10, and 14 persons were killed. The runaway car was a flat car loaded with timber. It broke loose from its train at the end of a steep grade and ran backward down grade into the following passenger car.

A VIOLENT WIND AND RAIN STORM visited the Island of Jamaica Nov. 5-10. Press reports of Nov. 15 estimate that about 50 persons lost their lives in the floods caused by the storm, and the property loss—principally at Kingston and to banana plantations on the north side of the island—is placed at $1,250,000. The storm began with a heavy gale Nov. 5 and had soon become a hurricane. The recorded rainfall from Nov. 6 to 10 was 48 ins. This is more than the average annual rainfall in New York City.

FAST LONG-DISTANCE TRAINS have been started by both the New York Central and the Pennsylvania R. R. lines between New York and St. Louis. Each of these roads started, on Nov. 7, trains which make the trip between the cities in exactly 24 hours. On the New York Central this distance is 1,174 miles, so that the average speed is about 49 miles per hour; on the Pennsylvania the distance is 1,050 miles and the average speed 44 miles per hour. Each of the trains has an all Pullman make-up and an extra fare is charged for the trip.

SIX PROMINENT FRENCH ENGINEERS were killed and a number of others seriously injured in an accident on an electric line in the south of France on Oct. 31. The railway, which is just being completed, runs from Villefranche-de-Confient to Bourg-Madame and contains, among other structures, a peculiar fixed type suspension bridge of 512 ft. span across the Cassagne Gorge. On the day of the accident a party of engineers had just completed an inspection trip to the bridge, which was being subjected to its final load tests, and had boarded an electric car on the new line to be carried to the nearest station. Owing to some difficulty with the driving mechanism of the car, it got away from its motorman on a 6% grade and, the brakes failing on wet rails, rapidly acquired a great speed and jumped the track on a curve, falling down into the adjacent gorge. Every member of the party was either killed or injured. The killed were Lt.-Col. Giscard, who had originated the type of bridge over the crossing at Cassagne and had designed the bridge there; Messrs. Hubert, Toulet, Borrallo and Clerc, all engineers in the French corps of Ponts et Chausées, and M. Bezault, the chief erector of the contracting company. Among those injured were M. Arnodin and M. Leinekugel Le Cocq, members of the firm who built the bridge. A recent issue of "Le Genie Civil" gives a full account of the accident.

BATTLESHIP "NORTH DAKOTA."—In our issue of Nov. 11, the speed trials of this latest and greatest battleship were noted. While the results there shown are notable, the interest of most engineers centers in the performance of the ship as affected by the use of steam turbines instead of reciprocating engines in the actual and guaranteed efficiency of her machinery rather than the fact that a maximum speed of 22.25 knots was reached in comparison with the required 21 knots. The accompanying tabulation of results, furnished by Mr. Walter B. Snow, 170 Summer St., Boston, shows a steaming radius, at 12 knots, of 9,000 nautical miles. At 19 knots it is 4,600 miles and at 21.5 knots per hour, it is 3,000 miles. In comparison with the "Delaware," sister ship of the "North Dakota," the latter uses 105 tons of coal per 24 hours, at a cruising speed of 12 knots, whereas the former uses 111 tons.

THE RESULTS OF OFFICIAL TRIALS OF U. S. BATTLESHIP "NORTH DAKOTA" (EQUIPPED WITH CURTIS TURBINES), NOVEMBER, 1909.

	3 hrs. of full power.	24-hr. trial at 19 knots.	24-hr. trial at 12 knots.
Actual average speed...	21.64	*19.24	12.05
R. p. m.	280.4	231.9	143.2
Shaft HP. of main turbines	31,400.	*16,710.	3,800.
I. HP. of engineer's auxiliaries	1,100.	*960.	400.
Water rate of main turbines only	13.6	14.11	20.5
Water rate for all engineer's purposes based on total HP.	13.96	15.29	22.3
Coal used, lbs, per hr..	54,400.	*27,550.	9,820.
Coal used, tons per 24 hrs.	583.	295.3	105.
Coal per hr. per shaft HP. of turbines.	1.74	*1.65	2.58
Coal per hr. per HP. for total HP.	1.68	*1.58	2.34
Coal per hr. of equivalent I. HP. based on 8% friction for reciprocating engine.	1.55	*1.46	2.15

*All figures given are official except those starred.

STANDARDIZATION TRIAL.

Highest speed on mile, uncorrected for tide, knots,	22.25
Mean of five high runs, knots	21.83
R.P.M. for 21 knots	283.
R.P.M. for 19 knots	228.8
R.P.M. for 12 knots	142.5
Max. shaft HP. developed on mile	35,150.

A BOSTON-IN-1915 EXPOSITION is being held during the month of November in the old Art Museum, Copley Square, Boston. This exposition is one of the means being taken by a number of enterprising citizens of Boston to secure the formulation and execution of plans designed to make Boston as nearly as possible an ideal city by the year 1915. Included in the present exposition are a number of loan collections of drawings and diagrams showing what has been done or is being proposed in the way of municipal improvement in other cities. The most notable exhibit in this class is a highly interesting and attractive series of large and small water-color drawings showing a very comprehensive scheme for improvements in the street plan, park system and water front of Chicago, including a magnificent civic center on and near the water front. Among the many instructive exhibits showing how municipal conditions may be improved in many of our cities with little or no expense over present practice, particular attention may be called to a couple of small relief plans of the lay-out of hilly residential sections not far from Boston. One of these shows the usual rectangular checker-board lay-out, with streets running up and down hill quite regardless of steepness of grades. The other and vastly improved scheme shows the streets laid out in general conformity to the contour lines of the district. The grades thus secured are all easy, and the general effect given by both the easy grades and curves gives a variety and grace that are in remarkable contrast with the high grades and general rigidity of the rectangular plan of the other districts.

TRACKLAYING ON THE WESTERN PACIFIC was completed on Nov. 1. This marks the formal completion of a new transcontinental railway, as the Western Pacific and the Wabash, controlled by affiliated interests, form a through route independent of connections. As the Chicago, Milwaukee & Puget Sound Ry. was completed only a short time ago, this makes two new Pacific railways opened in a single year.

THE NEW YORK SUBWAY, for which appropriations were made a few weeks ago, as noted in our issue of Nov. 4, was formally begun on Nov. 12, by a ground-breaking ceremony on the contract-section of William Bradley. The contracts which have been executed are the result of bids called and submitted about two years ago; the successful bidders have now signed the contracts in spite of the time which has elapsed.

SEEBACH-WETTINGEN RAILWAY LINE.—The cessation of experiments with single-phase, high-tension, electric traction on the Seebach-Wettingen line of the Swiss-Federal Rys., was noted in our issue of Nov. 4, in the article "Development of a Swiss Single-Phase Railway." In the "Schweizerische Bauzeitung," Oct. 23, is a note on the attitude of the Directors of The Federal Rys. It is stated that 110,000 francs ($2,200) had been voted to the Oberlikon Works as a share of the cost of making the experiments. This was acknowledged as a half of the excess over those expenditures agreed on for the regular operating period. The Directors of the Federal Rys. expressed the opinion that while the technical possibility of single-phase traction had been shown, yet a series of trials was needed with heavier loads and faster trains. The present equipment of the Seebach line, it was felt, would not adapt itself in its present condition or without carrying to completion the needed experiments, which demanded changes in superstructure transmission lines and power station.

Personals.

Mr. A. J. Davidson has resigned his position as President of the St. Louis & San Francisco R. R.

Mr. Harrison P. Eddy, M. Am. Soc. C. E., has been appointed a member of the advisory commission for the sewerage system of Milwaukee, Wis.

Mr. P. M. Brickley has resigned as City Engineer of Harvard, Ill., and has been succeeded by Mr. L. E. Converse, who was formerly his assistant.

Mr. W. F. Martin, Jun. Am. Soc. C. E., Engineer, U. S. Geological Survey at Pasadena, Cal., has been appointed Chief Engineer in charge of water supply investigations in Hawaii.

Mr. E. E. Kurtz has been appointed Assistant District Engineer of the New York Central & Hudson River R. R., in charge of territory covered by the Pennsylvania division, with office at Corning, N. Y.

Mr. J. D. Stack, Superintendent of the Colorado & Southern Ry. at Trinidad, Colo., has resigned to become Assistant Superintendent of the Sacramento division of the Southern Pacific Ry. at Sacramento, Cal.

Mr. C. R. Breck, formerly employed in the office of the Chief Engineer of the Southern Pacific Ry., has succeeded Mr. R. E. Hardaway as Chief Locating Engineer of projected lines of the Southern Pacific system in Guadalajara, Mex.

Mr. Samuel G. Thompson has been appointed Assistant Engineer of Motive Power of the Philadelphia & Reading Ry., with headquarters at Reading, Pa. The positions of Mechanical Engineer and Electrical Engineer have been abolished.

Mr. C. F. W. Felt, M. Am. Soc. C. E., Chief Engineer of the Gulf, Colorado & Santa Fe Ry., has been appointed Chief Engineer of the Atchison, Topeka & Santa Fe Ry. to succeed Mr. C. A. Morse, M. Am. Soc. C. E., who is now Chief Engineer of the entire Santa Fe system.

Mr. G. W. Vandersllce, formerly Division Superintendent of the National Rys. of Mexico at Chihuahua, has been appointed Superintendent of the western division of the Chicago Great Western R. R., with headquarters at Clarion, Iowa, to succeed Mr. A. E. Harvey, transferred.

Mr. Ralph Modjeski, M. Am. Soc. C. E., has been appointed Consulting Engineer to the city of Portland, Ore., in regard to the new Broadway Bridge over the Willamette River. He will have charge of both the design and construction of this bridge, which will cost about $1,500,000.

Mr. O. O. McReynolds, M. Am. Soc. C. E., who has spent the past two years on construction work and development of oil properties in the San Joaquin Valley near Bakersfield, Cal., has recently opened an office for the general practice of civil and mining engineering at 318 H. W. Hellman Bldg., Los Angeles, Cal.

Mr. George R. G. Conway, M. Am. Soc. C. E., of Monterrey, N. L., Mexico, has been awarded a Telford gold medal by the British Institution of Civil Engineers for his paper on "Aberdeen Main-Drainage Works; Girdleness Outfall Scheme." This paper was published in the "Proceedings" of the Institution of Civil Engineers, Vol. CLXXVII., Session 1908-9, Part III. Mr. Conway recently contributed to Engineering News an article on the floods at Monterrey, published in our issue of Sept. 23, 1909.

Mr. J. C. Wickersham, Mr. S. Arch Replogle and Mr. James Plummer have organized the Pennsylvania Inspection Bureau, Johnstown Trust Bldg., Johnstown, Pa., to carry on a practice as inspecting and testing engineers. Mr. Wickersham has been employed for many years as an inspector of steel for the U. S. Government; Mr. Replogle has been for the past two years General Manager of the Cambria Forge Co., and Mr. Plummer is in charge of the Pittsburg office of the Newport News Shipbuilding Co.

Mr. James Forgie, M. Am. Soc. C. E. and M. Inst. C. E., has become a partner in the firm of Jacobs & Davies, consulting engineers, 30 Church St., New York City. Mr. Forgie is Engineer of the North River division of the Pennsylvania Tunnel & Terminal R. R. and Deputy Chief Engineer of the Hudson & Manhattan R. R. Before coming to New York City to act as Chief Assistant Engineer for Mr. C. M. Jacobs on the Pennsylvania R. R. tunnels, he was associated in London for about 12 years with Mr. James H. Greathead, who developed the shield system of tunneling and with Sir Benjamin Baker and the firm of Mott & Hay in the construction of the London tunnel system. An article by Mr. Forgie on the construction of the Pennsylvania R. R. tunnels was published in Engineering News, Dec. 13, 1906.

Obituary.

James Gardner Sanderson, M. Am. Soc. C. E., of Scranton, Pa., died Nov. 15 in New York City after an illness of several weeks.

Thomas Greene Bush, a prominent ironmaster, died Nov. 11 at the Country Club near Birmingham, Ala., aged 61 years. He was President of the Shelby Iron Co., Anniston Water Supply Co., Mobile & Birmingham R. R., Gray Iron Ore Co., and the Imperial Coal & Coke Co.

John R. Moffitt, who is credited with the invention of improvements to the threshing machine, died Nov. 14 at his home in Denver, Colo., aged 84 years.

Ransom R. Cable, at one time President of the Chicago, Rock Island & Pacific Ry., died Nov. 12 at his home in Chicago, Ill., aged 75 years. Mr. Cable was born in Athens Co., Ohio, in 1834. He was engaged in the coal mining business at Rock Island, Ill., for a number of years and, in 1870, became President of the old Rockford, Rock Island & St. Louis R. R. Since 1877 he has been a director of the Chicago, Rock Island & Pacific Ry. In 1879-80 he was Assistant to the President of that railway and, in the last named year, he became Vice-President and General Manager. Three years later he became President and General Manager, retaining the presidency until June, 1898, when he became chairman of the board of directors. He retired from this position Jan. 1, 1903, but remained on the board to the time of his death.

Engineering Societies.

COMING MEETINGS.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION.
Dec. 2-4. Annual convention at Milwaukee, Wis. Secy., James C. Monaghan, 20 West 44th St., New York City.

NEW JERSEY SANITARY ASSOCIATION.
Dec. 3-4. Annual meeting at Laurel-in-the-Pines, Lakewood, N. J. Secy., J. A. Exton, 75 Beech St., Arlington, N. J.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.
Dec. 6. Annual meeting in New York City. Secy., Wm. H. Ross, 154 Nassau St., New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
Dec. 7-10. Annual meeting at New York City. Secy., C. W. Rice, 29 West 39th St., New York City.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.
Dec. 8-10. Annual meeting at Philadelphia, Pa. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS.
Dec. 14-15. Annual meeting at New York City. Secy., Percy H. Wilson, Land Title Bldg., Philadelphia, Pa.

AMERICAN INSTITUTE OF ARCHITECTS.
Dec. 14-16. Annual convention at Washington, D. C. Secy., Glenn Brown, The Octagon, Washington, D. C.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 27. Annual meeting at Boston, Mass. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS.
Dec. 28-29. Annual meeting at Ames, Iowa. Secy., L. W. Chase, University of Nebraska, Lincoln, Neb.

MONTANA SOCIETY OF ENGINEERS.
Jan. 6-8. Annual meeting at Butte, Mont. Secy., Clinton H. Moore, Butte, Mont.

MICHIGAN ENGINEERING SOCIETY.
Jan. 12-14. Annual meeting at Lansing, Mich. Secy., Alba L. Holmes, 574 Wealthy Ave., Grand Rapids, Mich.

INDIANA ENGINEERING SOCIETY.
Jan. 13-15. Annual convention at Indianapolis, Ind. Secy., Chas. Brossmann, Union Trust Bldg., Indianapolis, Ind.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
Jan. 18-20. Annual meeting at New York City. Secy., W. M. Mackay, P. O. Box 1818, New York City.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 19-20. Annual meeting at New York City. Secy., Chas. W. Hunt, 220 West 57th St., New York City.

CANADIAN SOCIETY OF CIVIL ENGINEERS.—A meeting of the mechanical section was held at Montreal Nov. 11, at which Mr. G. L. Guillet presented an illustrated paper on "The Use of Alcohol in an Internal Combustion Engine."

BROOKLYN ENGINEERS' CLUB.—At the meeting of Nov. 11, Mr. Walter E. Spear presented a paper entitled "Brooklyn's Water Supply," which defined the present situation in Brooklyn and the measures needed to prevent a shortage before water from new sources becomes available.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.—At the November meeting in the Engineering Societies' Bldg., New York City, Nov. 12, Mr. Cary T. Hutchinson presented a paper entitled "The Electric System of The Great Northern Ry. Co., at Cascade Tunnel." The major part of this paper is reprinted elsewhere in this issue. In the discussion of the paper, the general trend of opinion was that the use of three-phase induction motors on the locomotives and the other peculiarities of the installation made necessary thereby, was justified as best satisfying the conditions of the particular problem.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.—Papers to be presented at the annual meeting in Philadelphia, Dec. 8-10, are announced as follows:

Dec. 8.—"Natural Draft Gas Producers and Gas Furnaces," Ernest Schmatolla; "Commercial Extraction of Grease and Oils," Wm. M. Booth; "The Chemical Industries of America," Chas. E. Munroe; address of the retiring president, Samuel P. Sadtler.

Dec. 10.—"Multiple-Effect Distillation," F. J. Wood; "Advantages of the Multiple-Effect Distillation of Glycerine and Other Products," A. C. Langmuir; "Reclaiming of Waste India Rubber," S. P. Sharples; "Materials for Textile Chemical Machines," Frederick Dameth; "The Manufacture of Carbon Bisulphide," E. R. Taylor; "Chemical Composition of Illinois Coal" and "Heat Efficiency of Smokeless Combustion and Heat Absorbing Capacity of Boilers," A. Bement.

Dec. 9 will be devoted to excursions to chemical industrial plants and other excursions will be held on the afternoons of Dec. 8 and 10. Cement plants at Allentown, Pa., will be visited on Dec. 11.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—The 30th annual meeting will be held in the Engineering Societies' Building, 29 West 39th St., New York City, Dec. 7-10. The social features of the meeting will be in charge of the members resident in and about New York under the immediate direction of a local committee of which Mr. Wm. D. Hoxie is chairman.

For the afternoon of Dec. 8, an excursion is planned for both members and guests and in the evening there will be a lecture on agricultural machinery. The professional sessions will be held in the morning and afternoon of Dec. 9 and on Friday morning, Dec. 10. The meeting of the gas-power section will take place Thursday afternoon simultaneously with the general session of that date, and the reception for members and guests will be held Thursday evening. Papers assigned to the annual meeting are announced as follows:

Dec. 9.—"Tests on a Venturi Meter for Boiler Feed," Chas. M. Allen; "The Pitot Tube as a Steam Meter," Geo. F. Gebhart; "Efficiency Tests of Steam Nozzles," F. H. Sibley and T. S. Kemble; "An Electric Gas Meter," C. C. Thomas. Afternoon: "Tan Bark as a Boiler Fuel," David M. Myers; "Cooling Towers for Steam and Gas-Power Plants," J. R. Bibbins; "Some Studies in Rolling Mill Engines," W. P. Caine; "An Experience With Leaky Vertical Fire Tube Boilers" and "The Best Form of Longitudinal Joint for Boilers," F. W. Dean; (gas-power section) "Testing Suction Gas Producers With a Koerting Ejector," C. M. Garland and A. P. Krats.

Dec. 10.—"The Bucyrus Locomotive Pile Driver," Walter Ferris; "Line-Shaft Efficiency, Mechanical and Economic," Henry Hess; "Pump Valves and Valve Areas" and "A Report on Cast-Iron Test Bars," A. F. Nagle.

In addition to these papers there will be several reports submitted by committees of the gas-power section.

NEW ENGLAND WATER WORKS ASSOCIATION.—The first of the usual series of winter meetings of the association was held in Boston on Nov. 10. After the luncheon, which for so long had been a pleasant and valuable feature of these meetings, Mr. William S. Johnson, M. Am. Soc. C. E., of Boston, read a paper in which he discussed groundwater-supplies, with particular reference to Massachusetts. The percentage of Massachusetts water-works relying upon groundwater for their supply has increased from 12% in 1879 to about 40% in 1909. Practically none of the municipalities of the state depend upon deep wells, but all, except for one or two instances of supplementary well supplies, draw from shallow wells instead.

Under the conditions of widely varying water-bearing formations which prevail in Massachusetts, Mr. Johnson stated, little use can be made of formulas or other means of forecasting the yield of wells prior to actual test. On this account, and also because of the attitude of the State Board of Health, pumping tests are generally made before final plans for well supplies are drawn. Such tests should, and usually do, take into account both quantity and quality of the water.

Arguments both for and against groundwater-supplies were reviewed by Mr. Johnson. Groundwater-supplies are generally safer and often less costly, both in the way of construction and operation, than surface supplies. The chief objection to their use is uncertainty as to quantity and quality after they have been in service for some years. Increasing quantities of iron in the water, as time goes on, have given rise to considerable trouble at several places in Massachusetts, leading in some cases to the adoption of a new source of supply and in others to the provision of iron-removal works.

Mr. Johnson's paper was discussed by a considerable number of members, most of whom agreed with and reinforced his arguments in favor of groundwater-supplies.

A paper on water-works accounting, with special reference to depreciation, by Mr. Harvey S. Chase, M. Am. Soc. M. E., of Boston, which was scheduled for this meeting, was postponed owing to the absence of the author, as was also postponed a committee report by Mr. F. A. Barbour, M. Am. Soc. C. E., of Boston, on the depth of laying water-pipe. A progress report was made in behalf of the Committee on Standard Specifications for Fire Hydrants.

The next meeting of the association will be held in Boston on Dec. 8.